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Viavattine

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(54) **ELECTROCHEMICAL CELL WITH A DIRECT CONNECTION BETWEEN A FEEDTHROUGH PIN AND AN ELECTRODE STACK**

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(75) Inventor: **Joseph Viavattine**, Vadnais Heights, MN (US)

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(73) Assignee: **Medtronic, Inc.**, Minneapolis, MN (US)

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(*) Notice: Subject to any disclaimer, the term of this patent is extended or adjusted under 35 U.S.C. 154(b) by 225 days.

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H01M 10/04	(2006.01)
H01M 10/0585	(2010.01)

Primary Examiner — Milton I Cano

Assistant Examiner — Jimmy K Vo

(52) **U.S. Cl.**

CPC **H01M 2/266** (2013.01); **H01M 10/0585** (2013.01); **H01M 2/06** (2013.01); **H01M 10/0436** (2013.01); **Y02E 60/12** (2013.01)
USPC **429/153**; 429/1; 429/152; 429/246

(57)

ABSTRACT

(58) **Field of Classification Search**

USPC 429/1, 59, 62, 115, 128, 129, 130, 152, 429/153, 158, 160, 161, 162, 178, 179-211, 429/233, 241, 246, 615; 29/623.4; 607/30, 607/36

A battery comprises a battery case forming a substantially sealed enclosure and an electrode stack within the enclosure. The electrode stack includes a first set of electrode elements and a second set of electrode elements. The electrode elements in the second set alternate with the electrode elements in the first set within the electrode stack. A conductive tab extends from each of the electrode elements in the first and second sets, wherein each of the conductive tabs in the first set forms an aperture, wherein the apertures are coincident with each other. The battery further comprises a feedthrough including a feedthrough pin extending through the battery case and through each of the coincident apertures, wherein the feedthrough pin serves as a positive terminal for the battery.

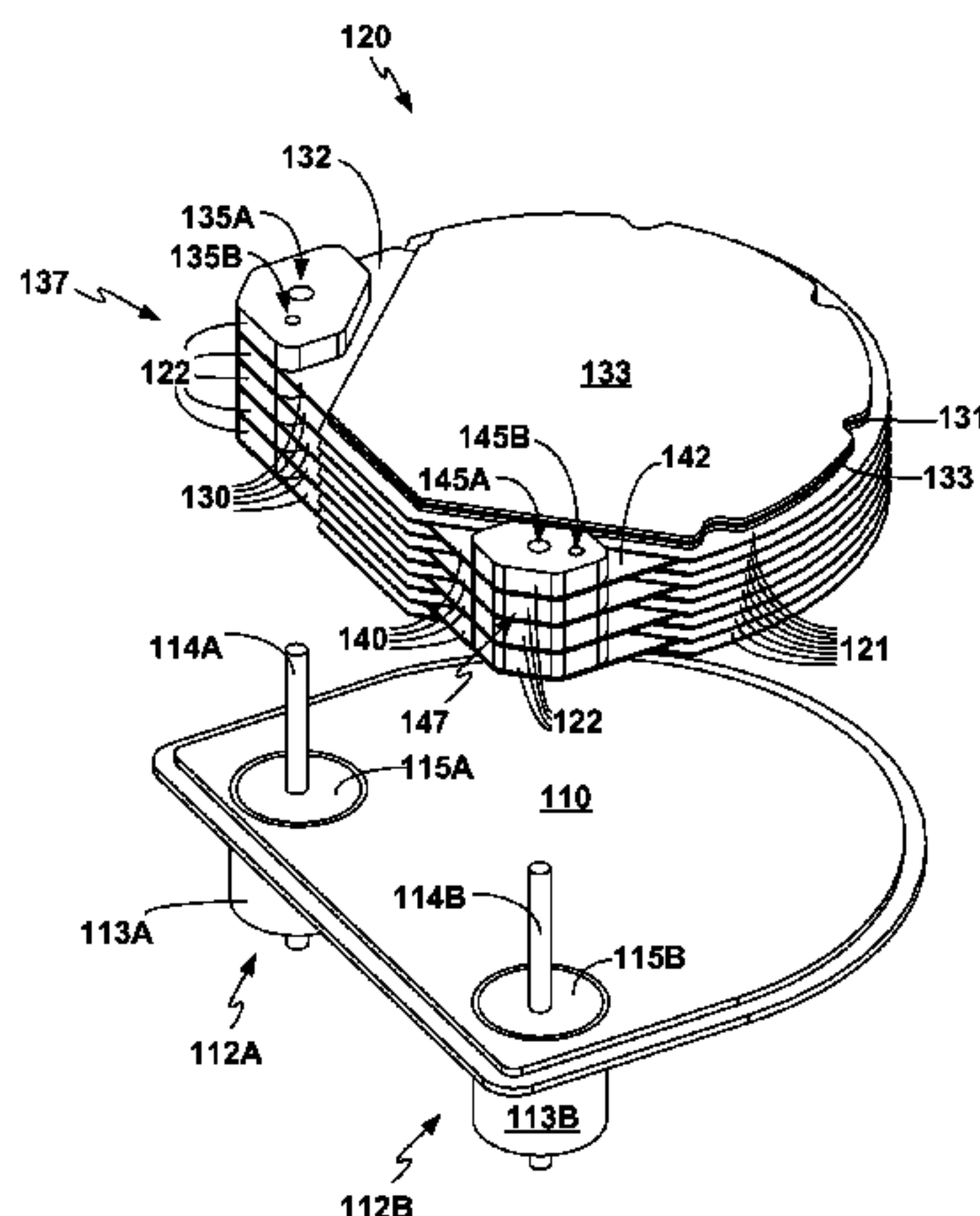
See application file for complete search history.

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4 Claims, 8 Drawing Sheets



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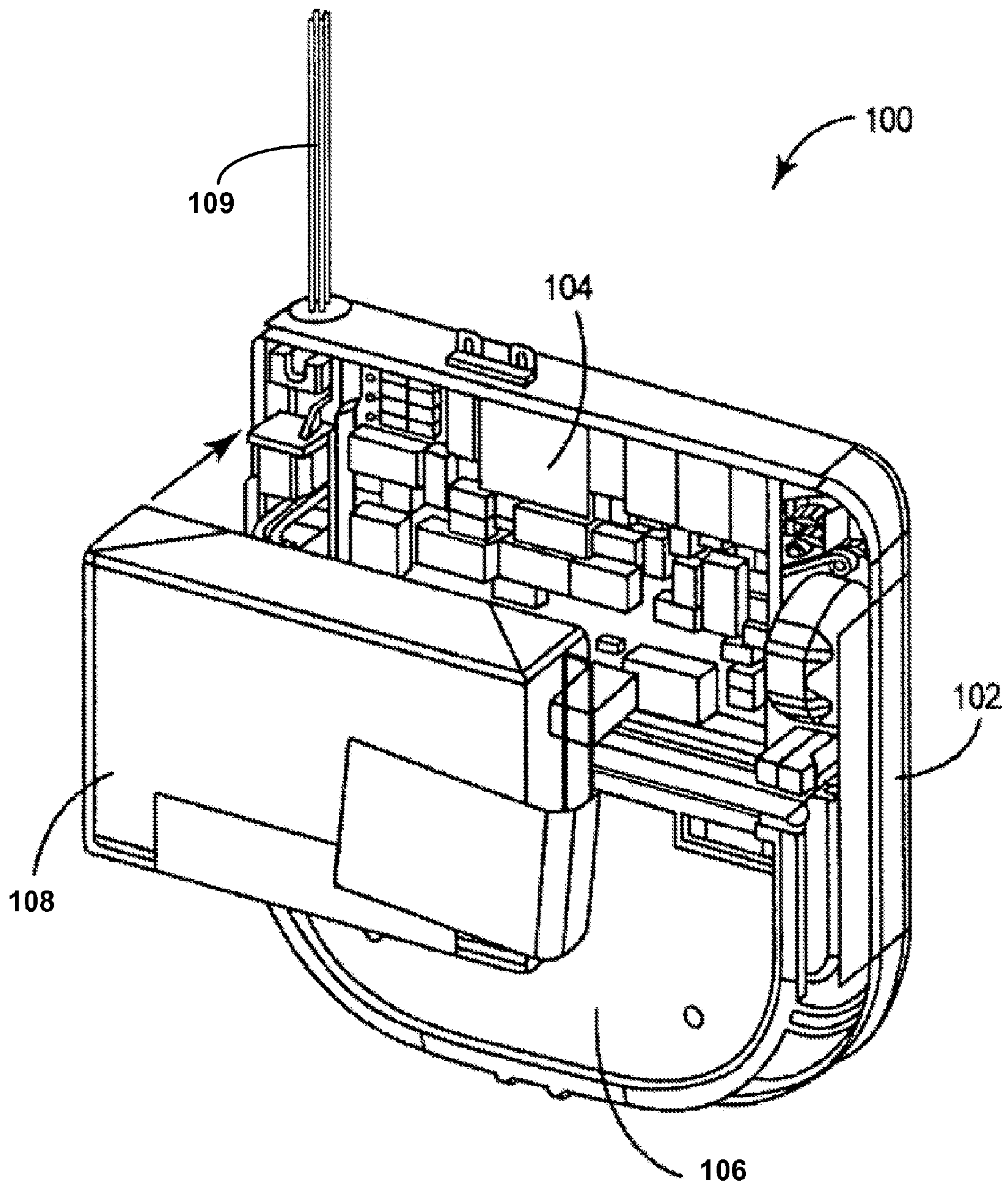


FIG. 1

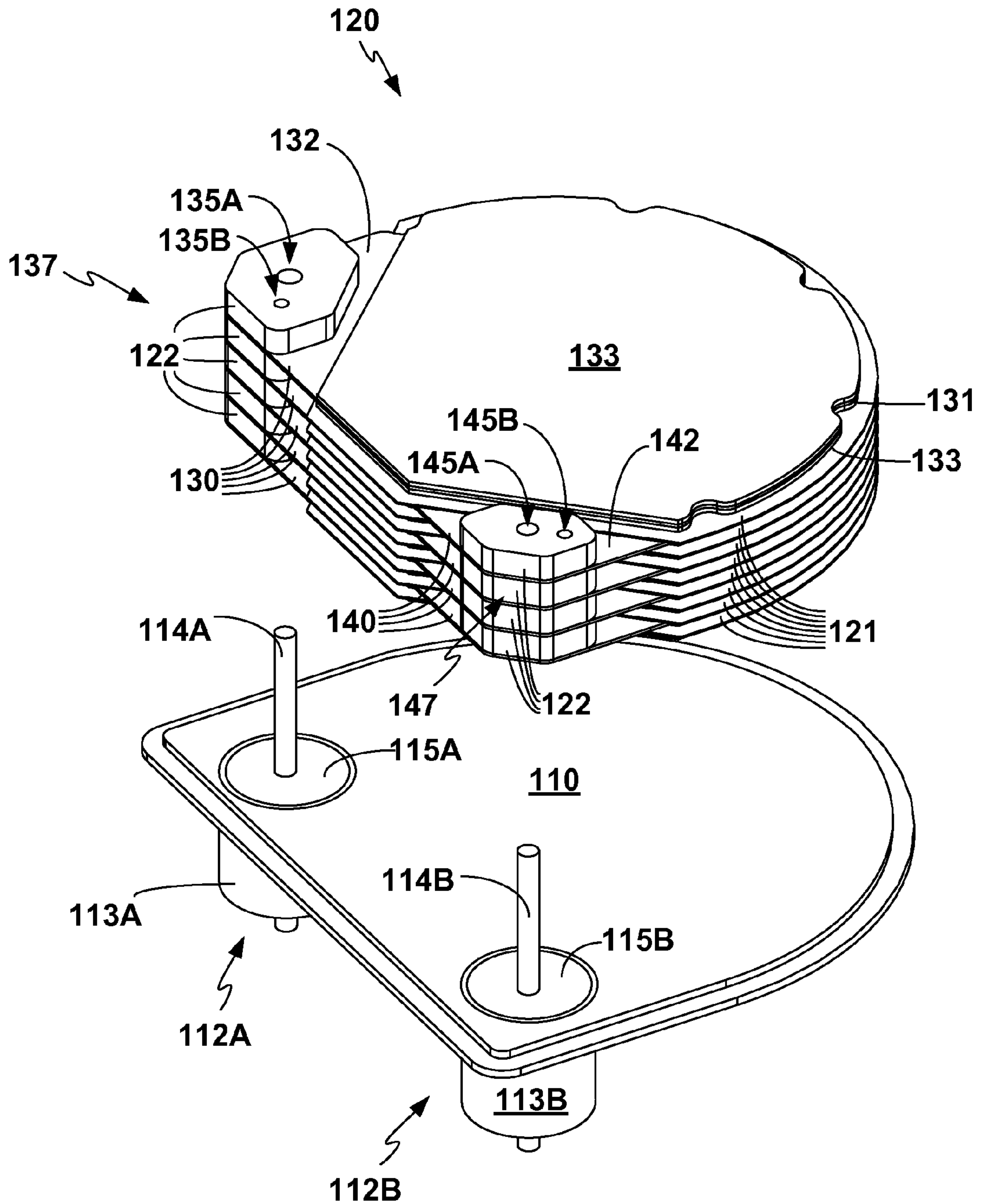


FIG. 2

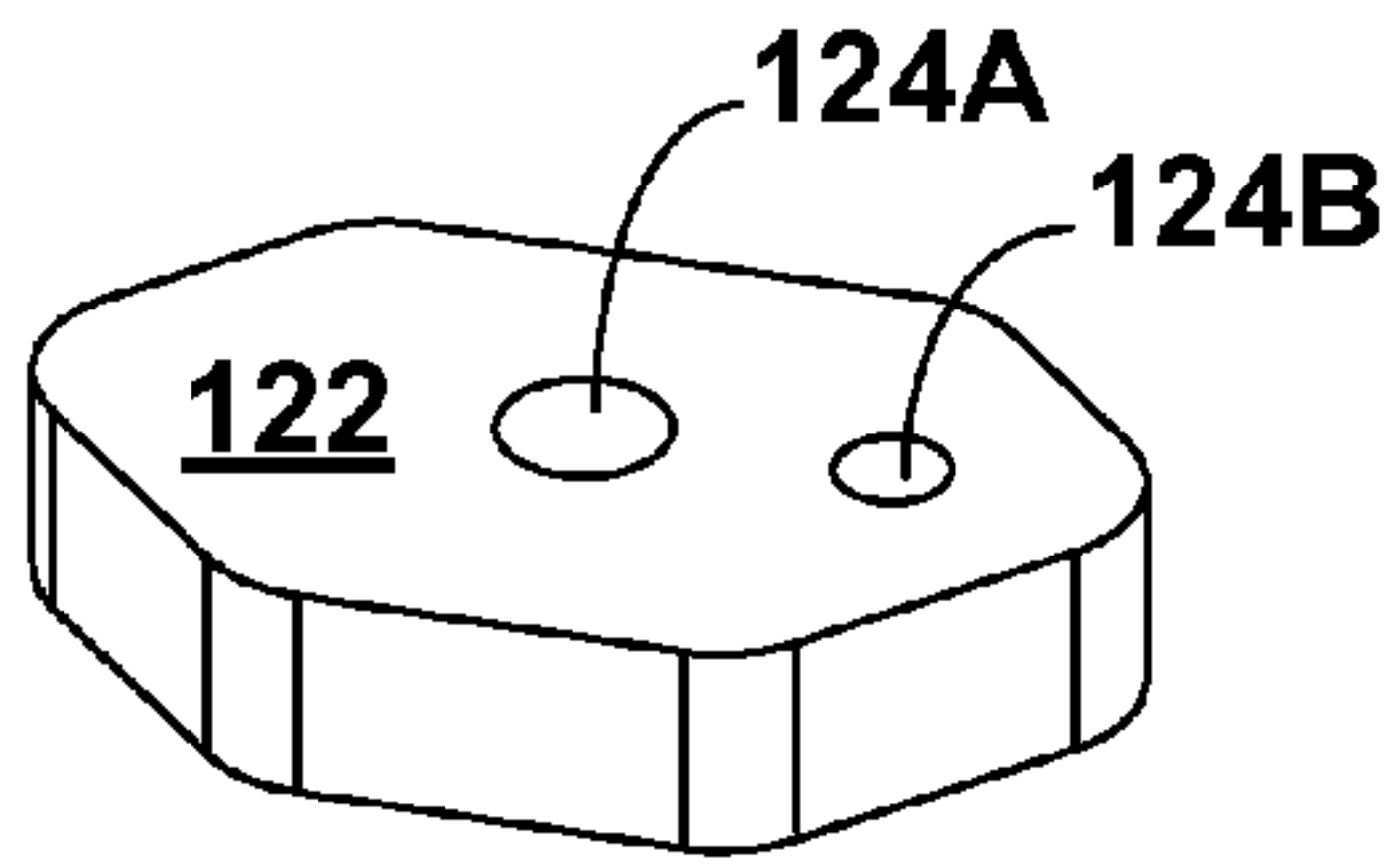


FIG. 3

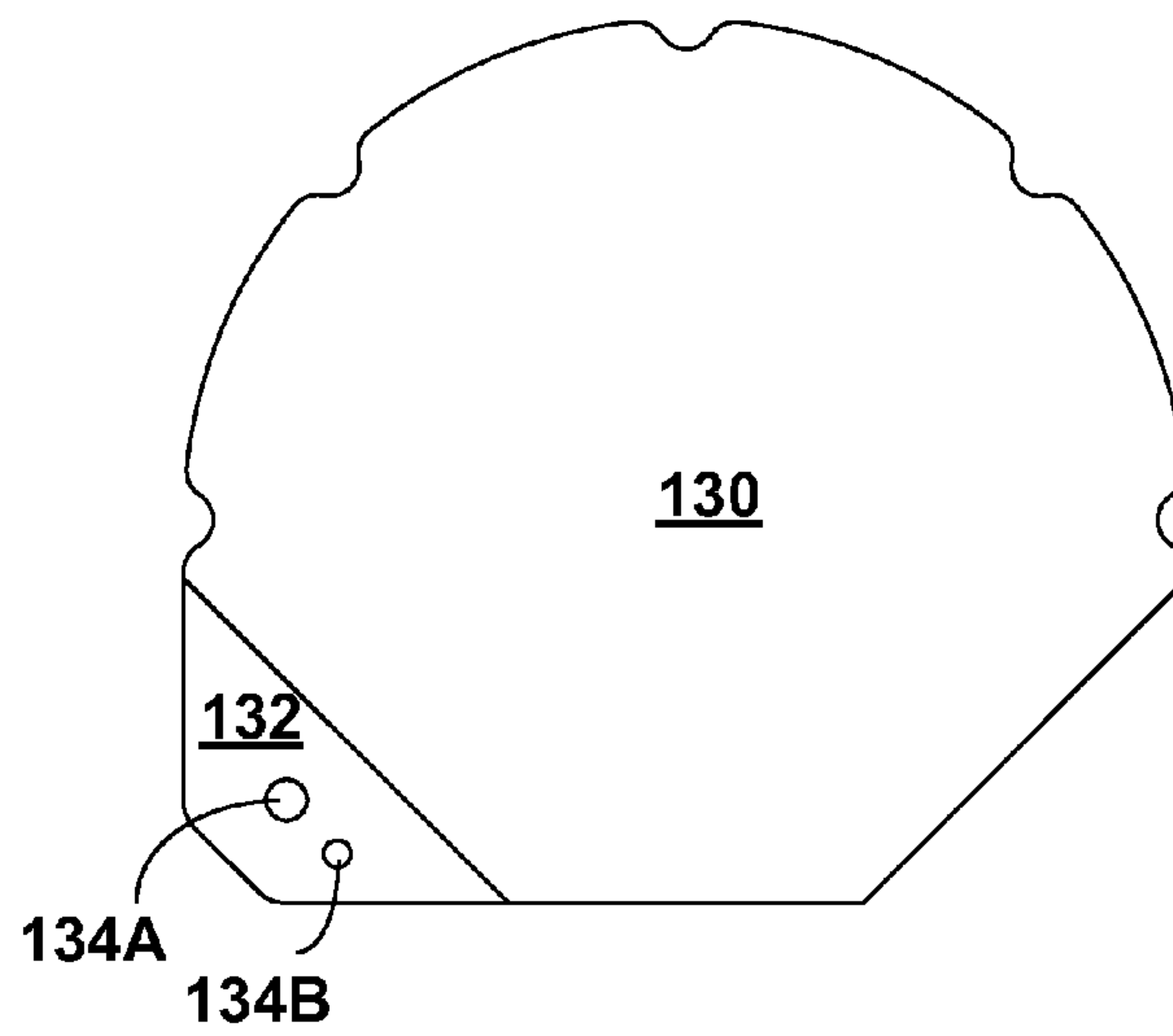


FIG. 4

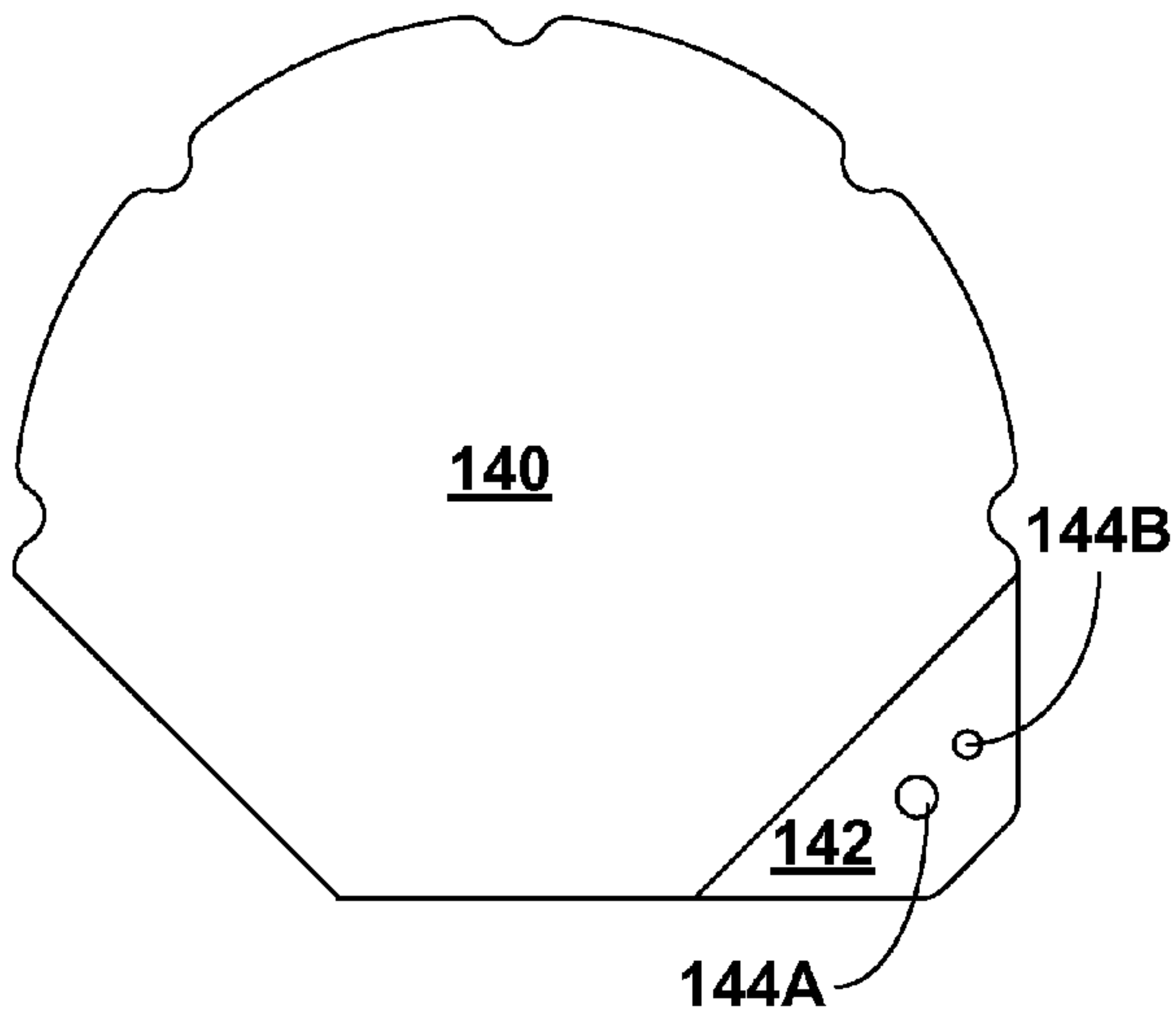


FIG. 5

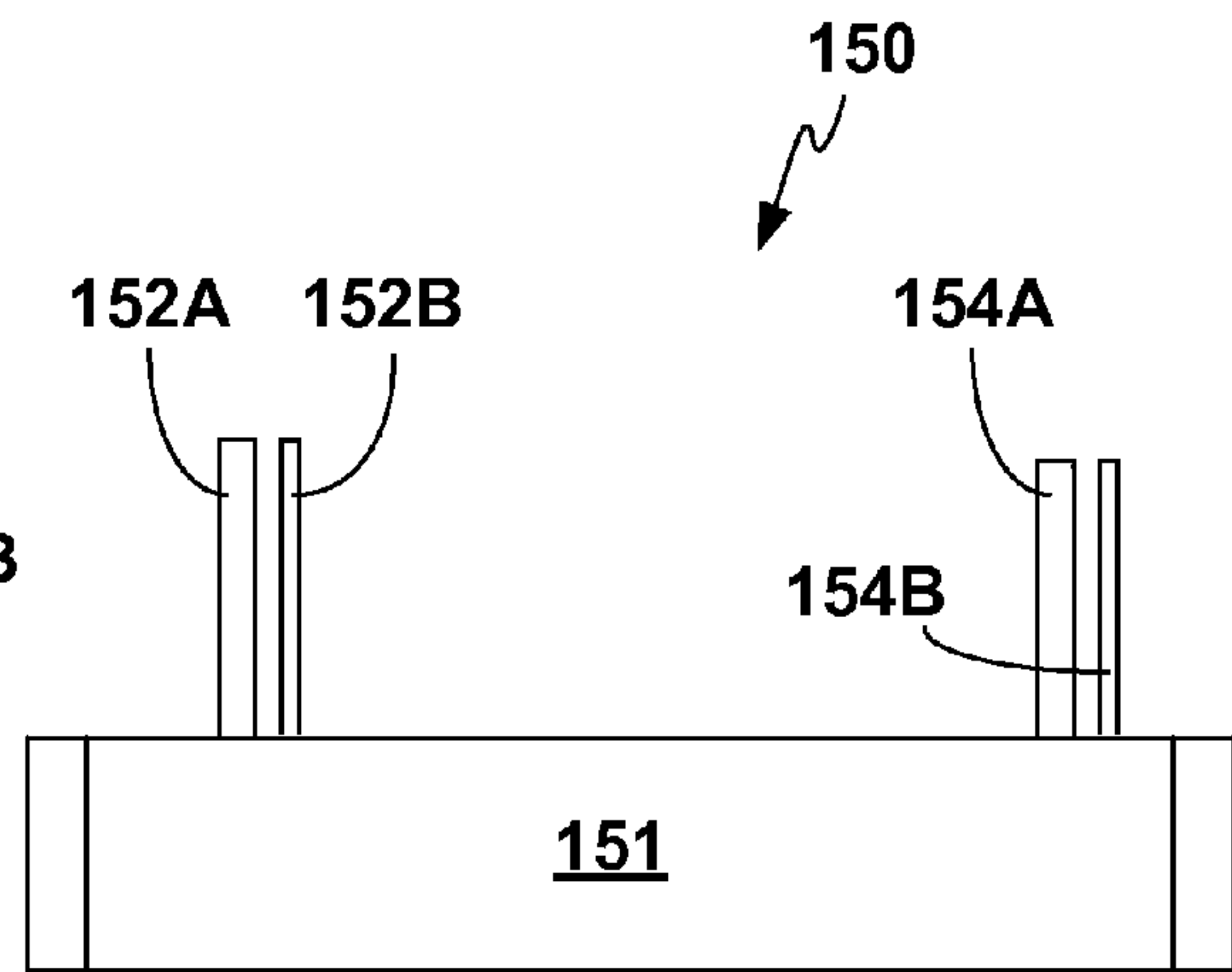


FIG. 6

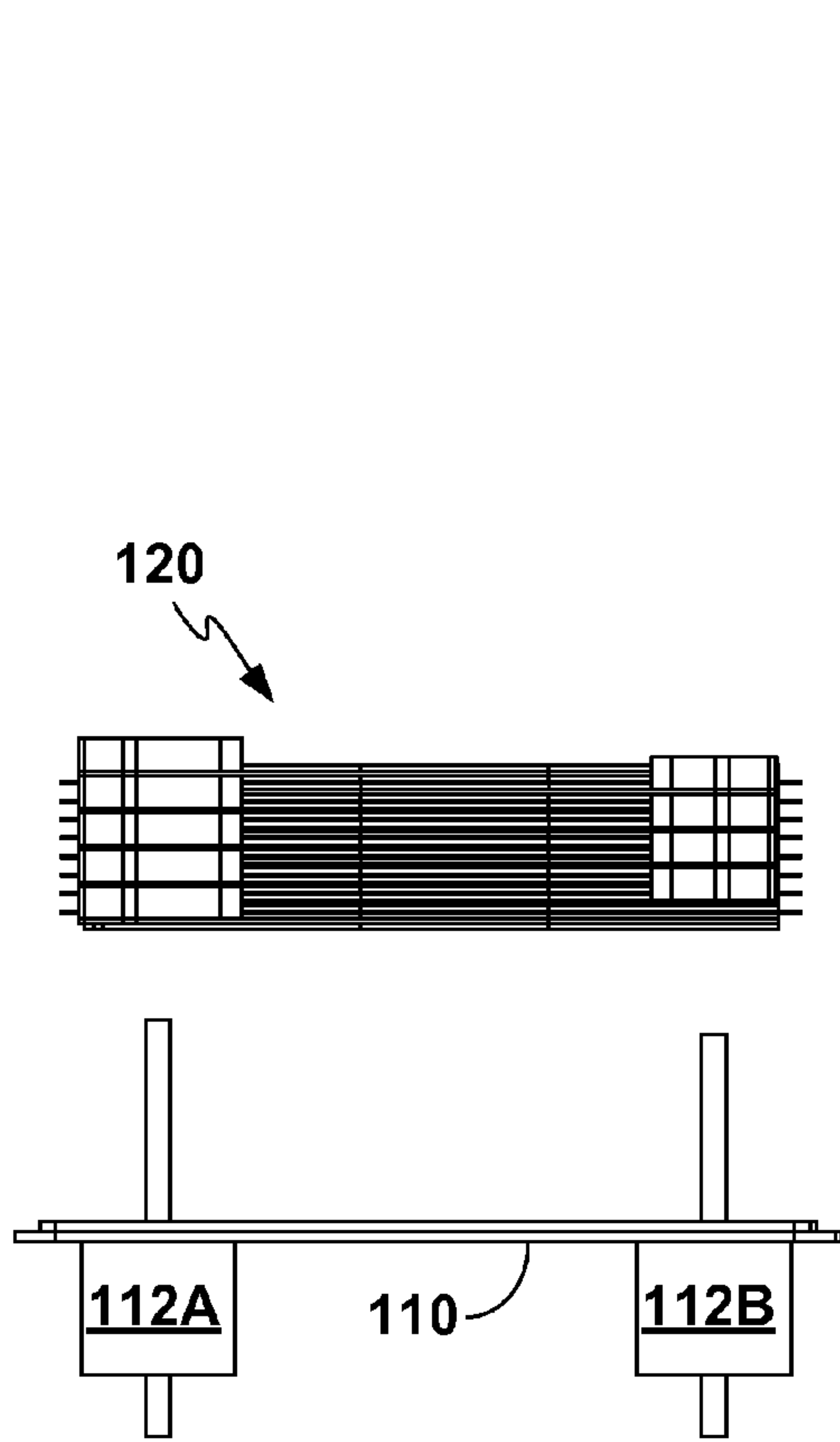


FIG. 7A

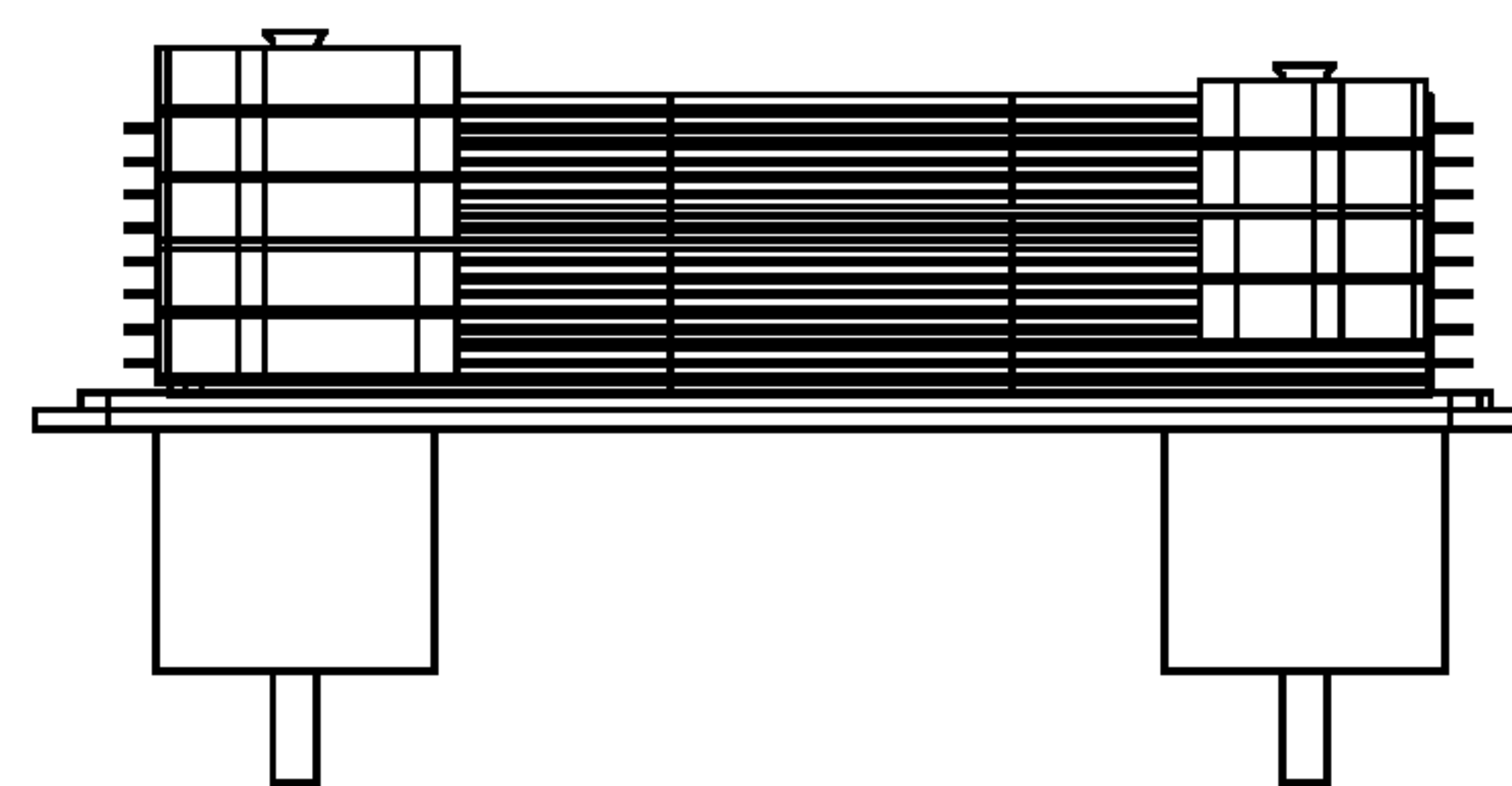
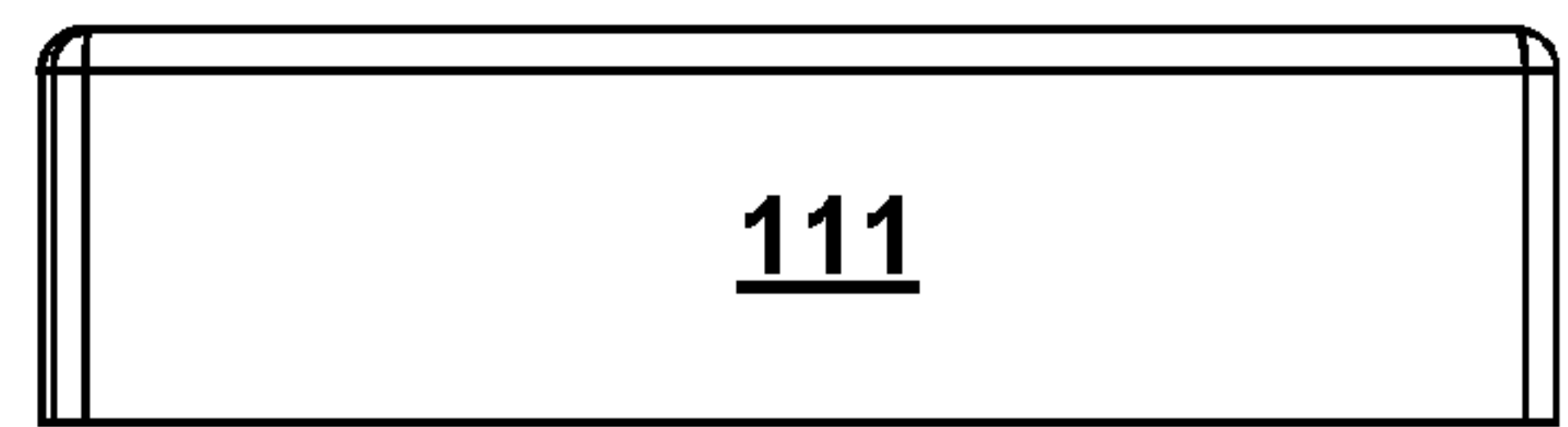


FIG. 7B

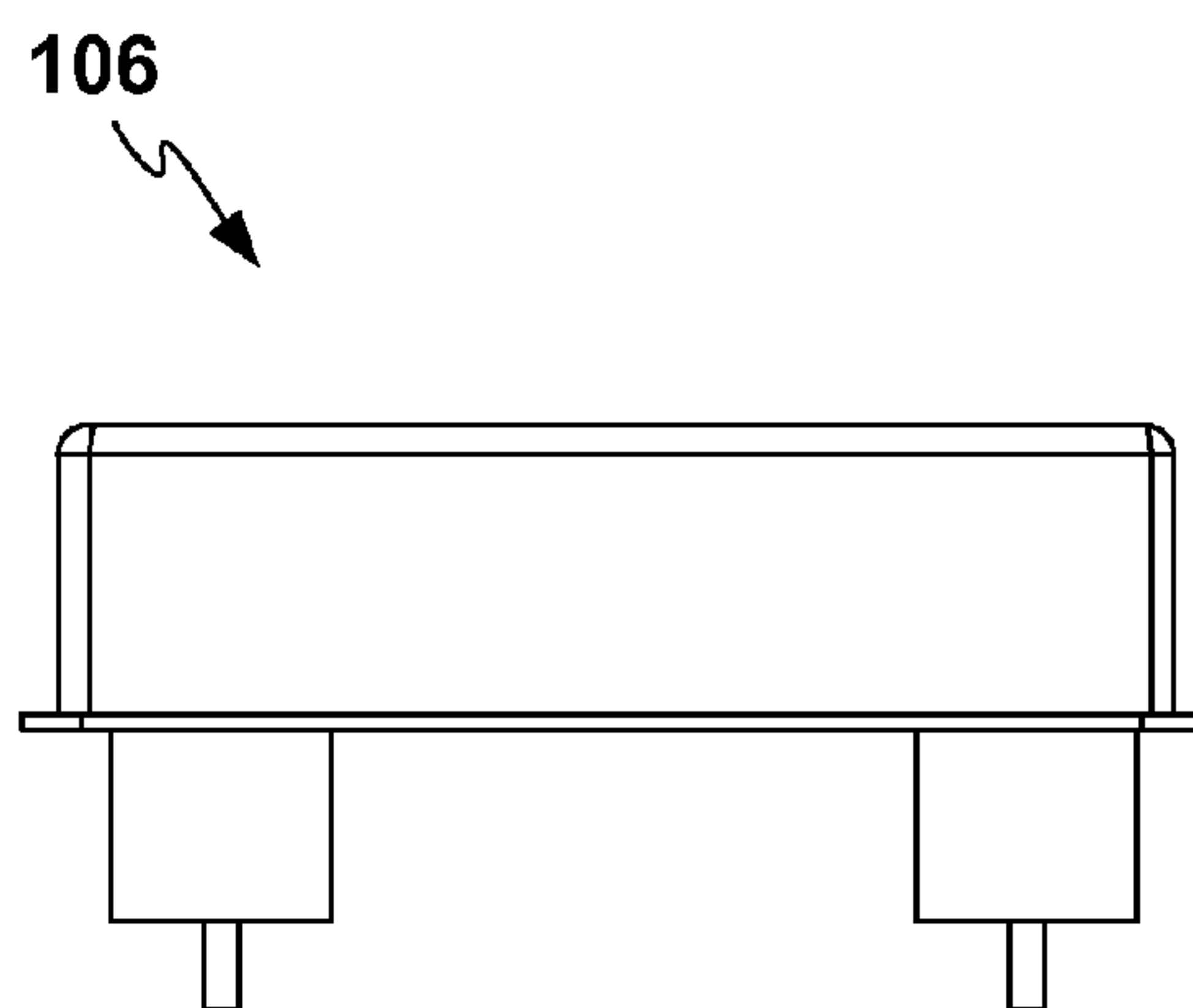


FIG. 7C

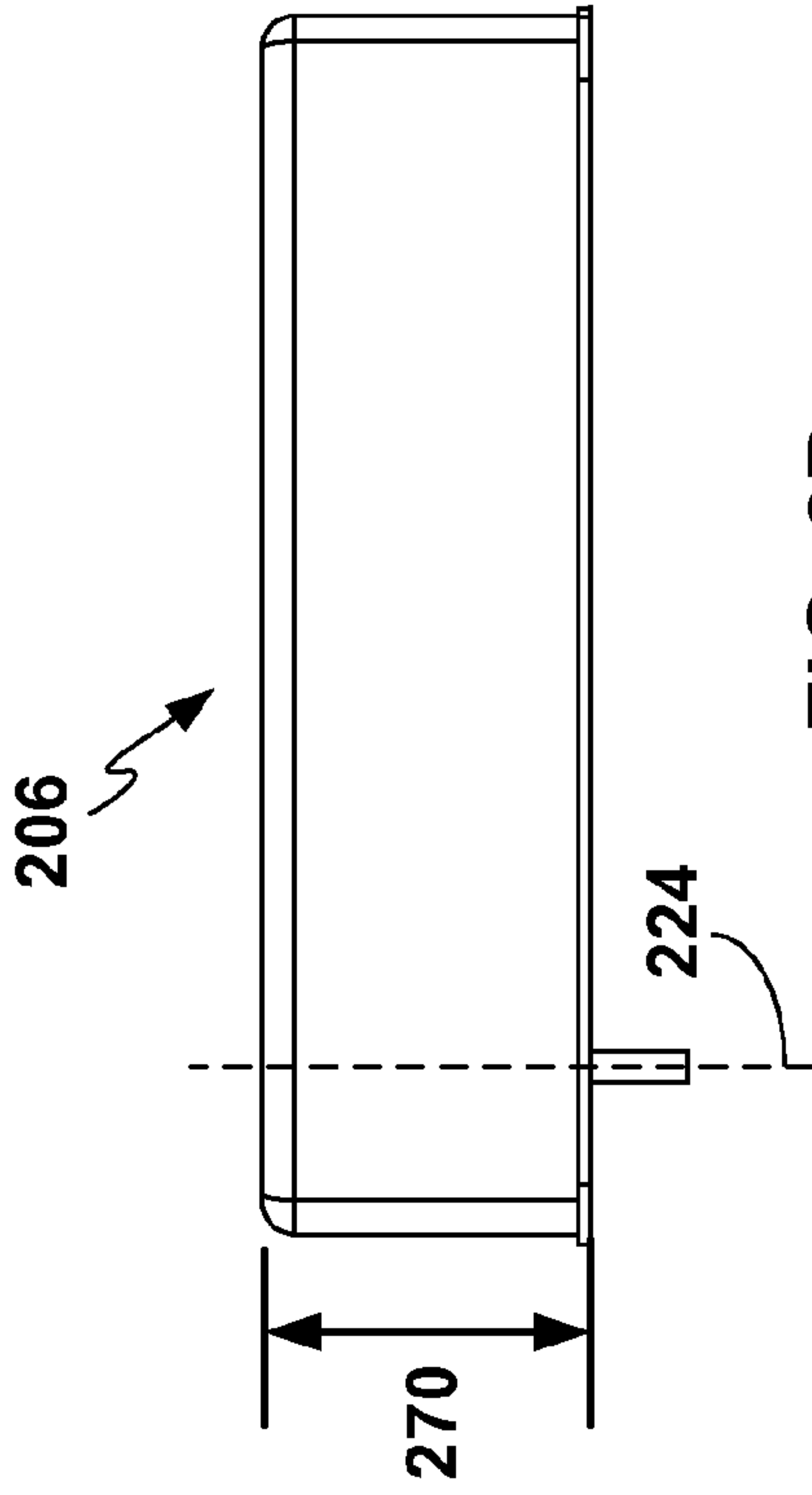


FIG. 8B

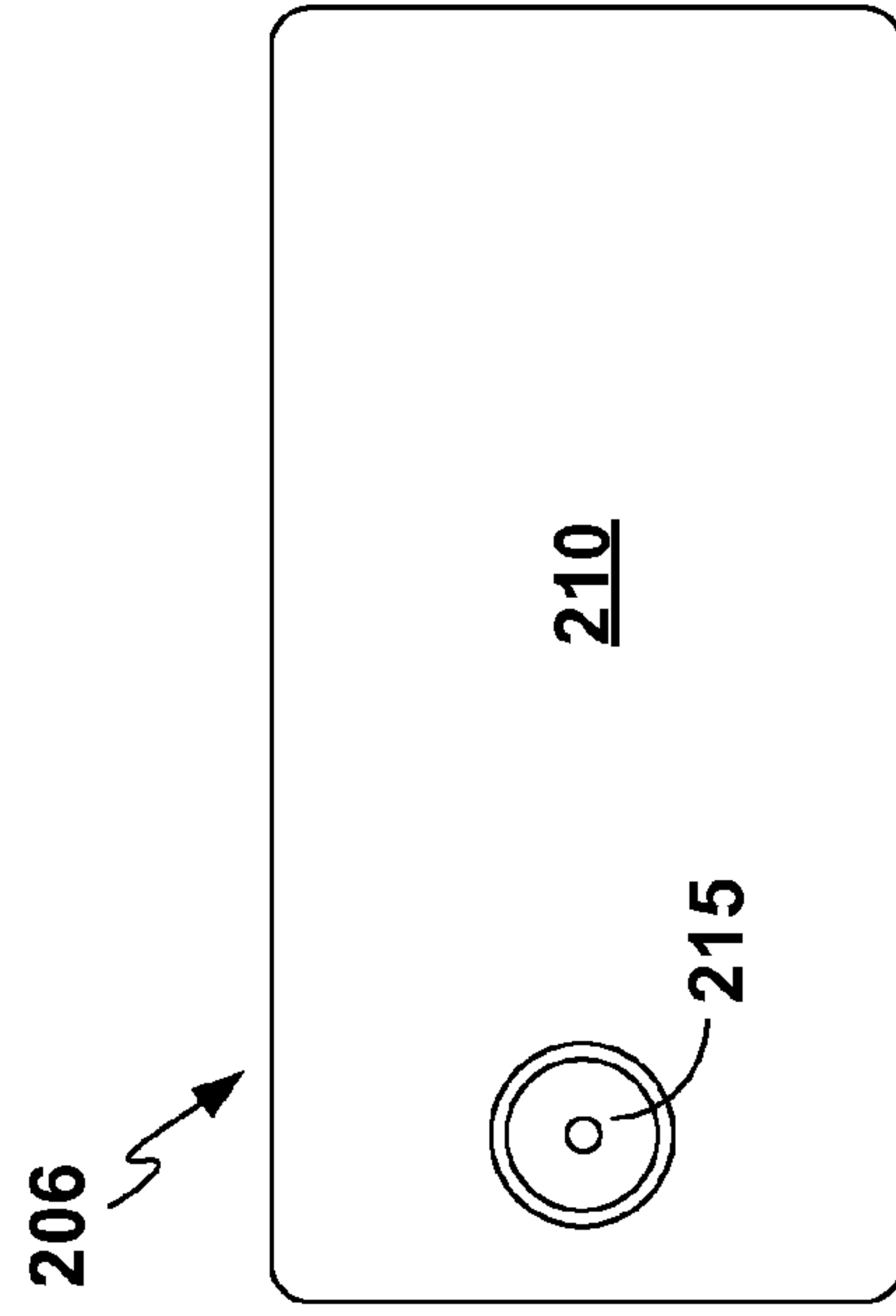


FIG. 8C

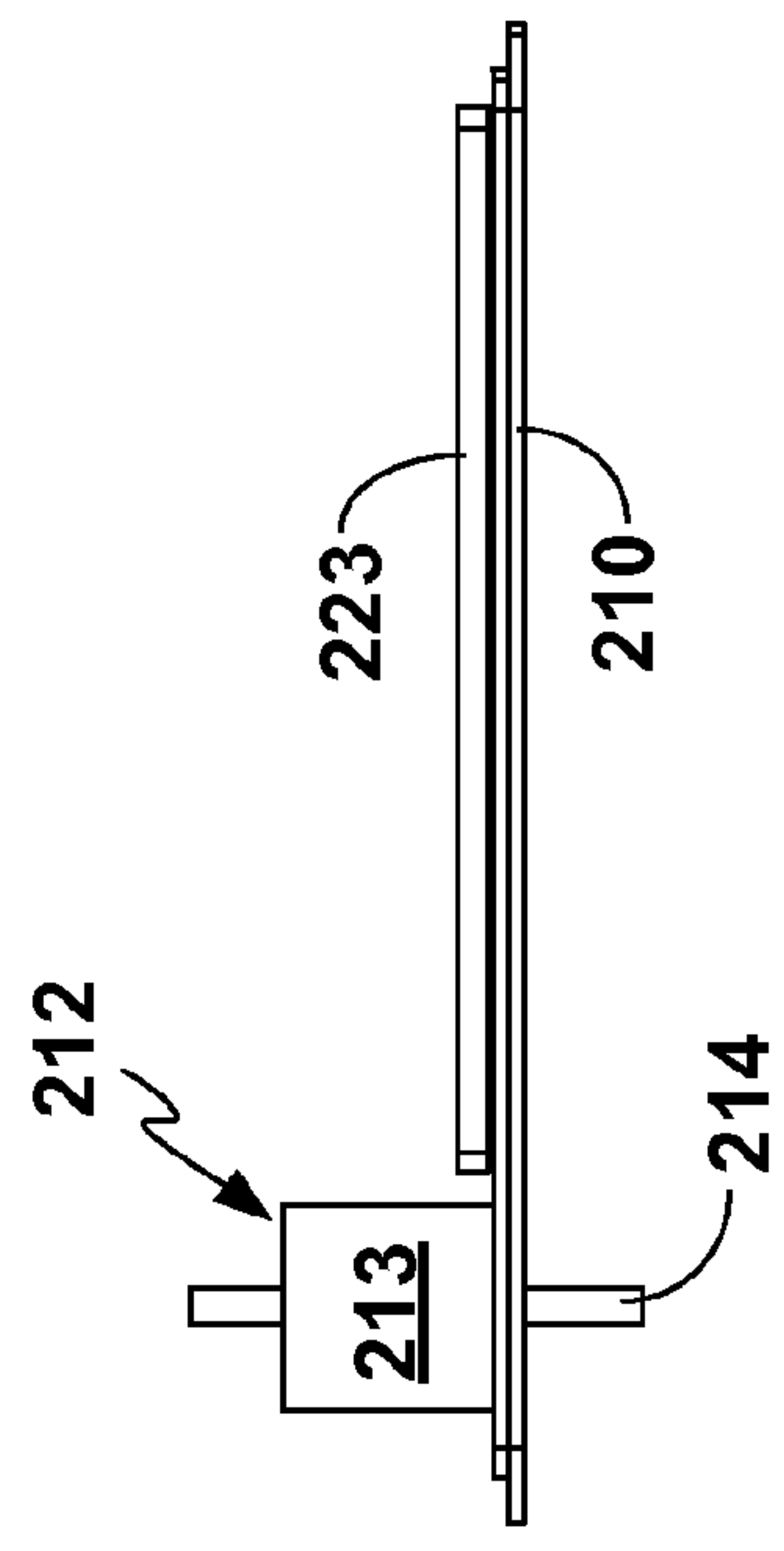
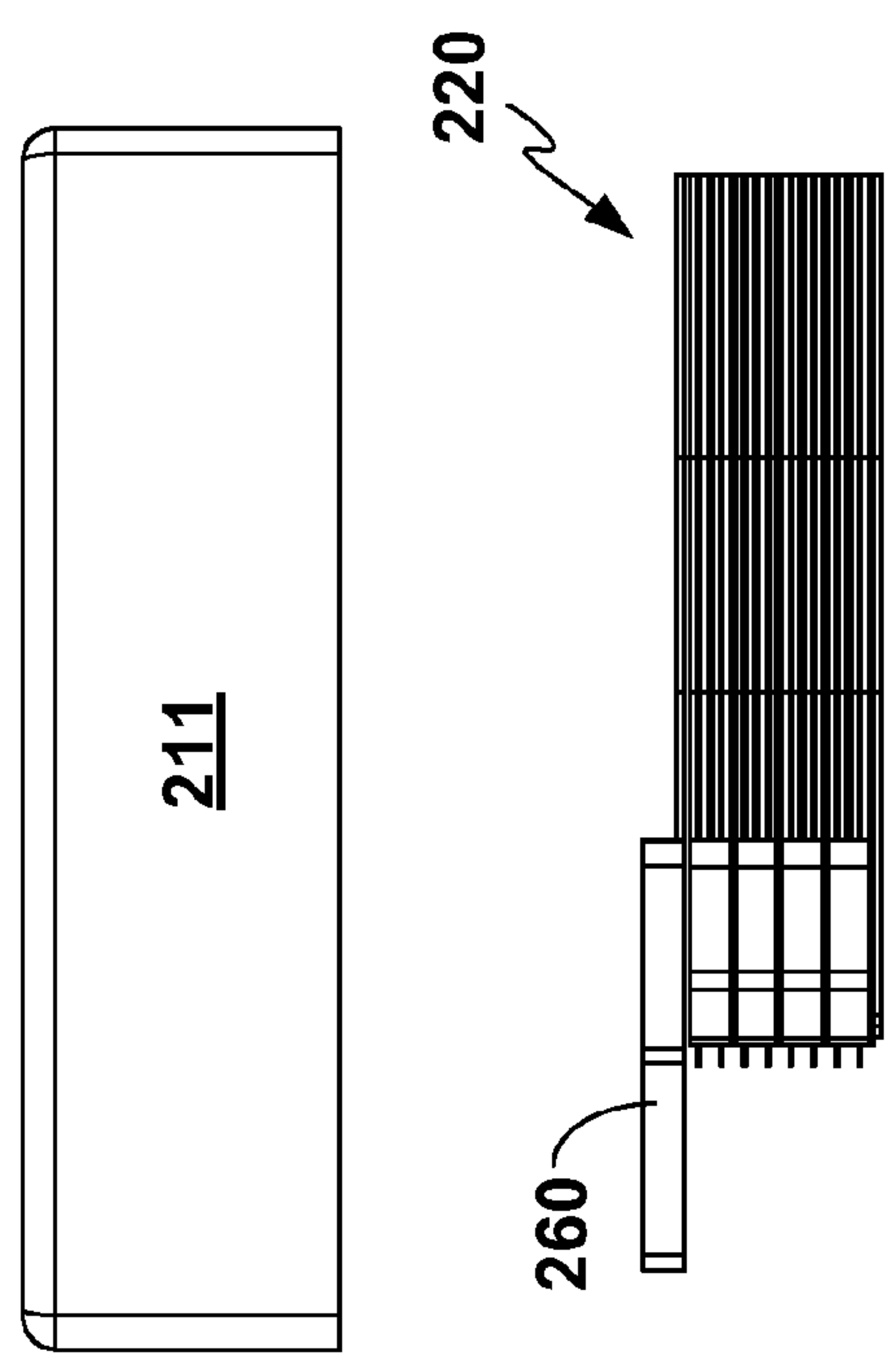


FIG. 8A

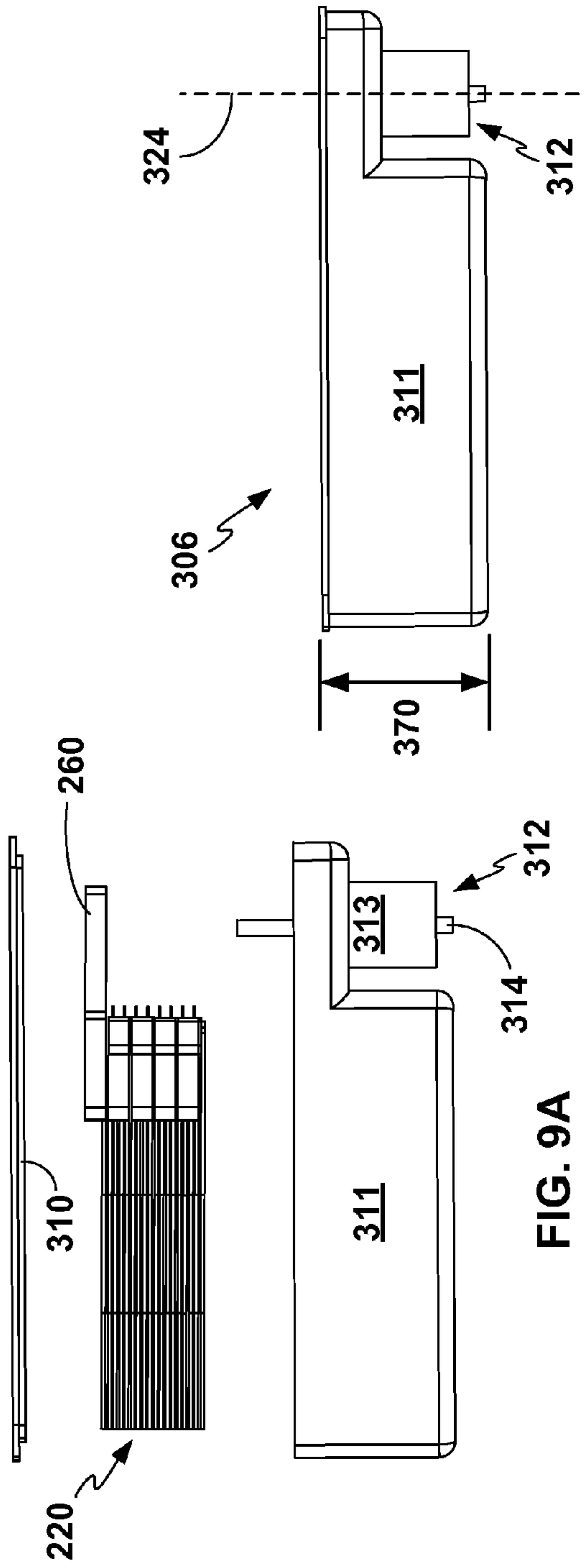


FIG. 9B

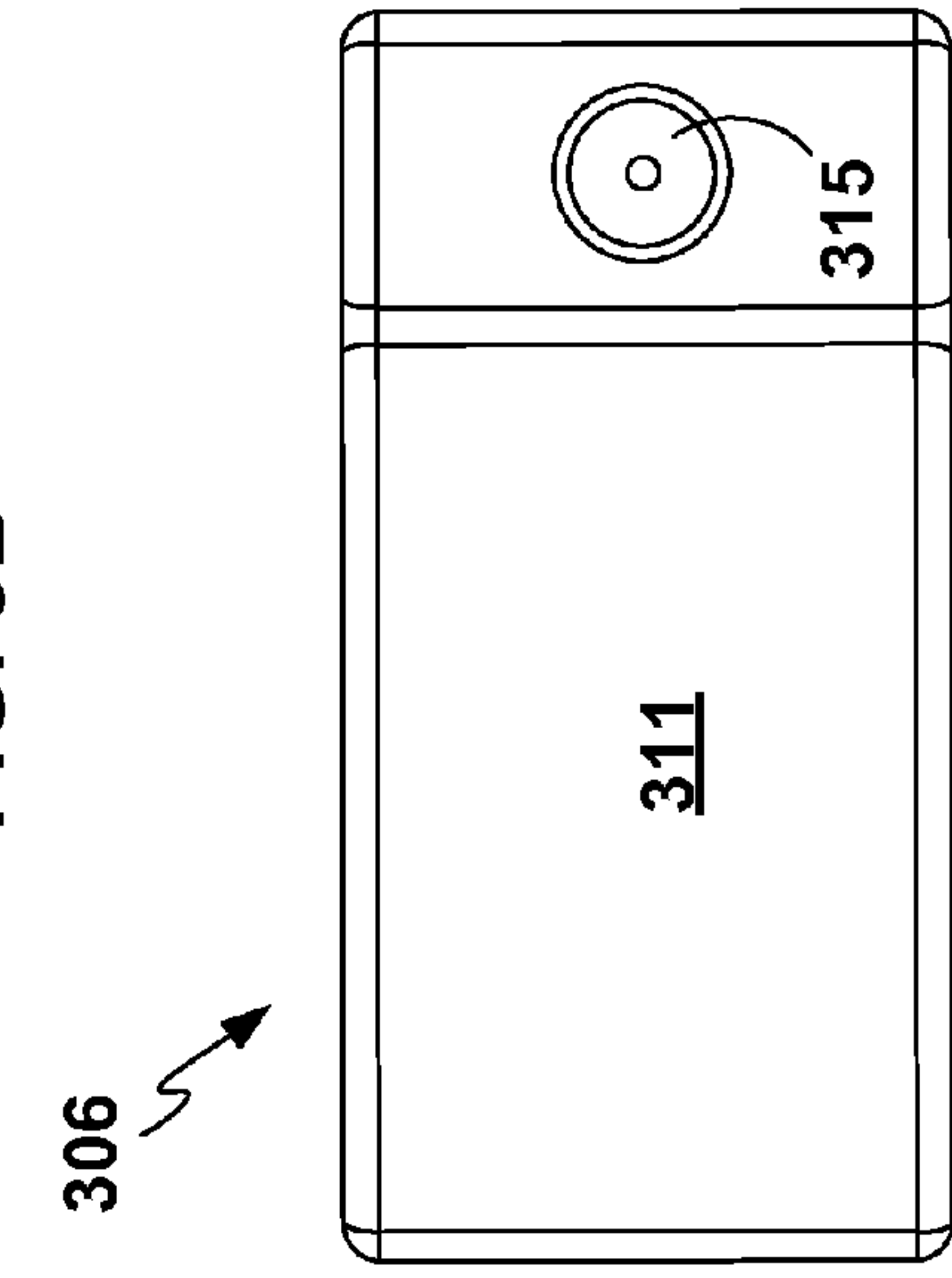


FIG. 9C

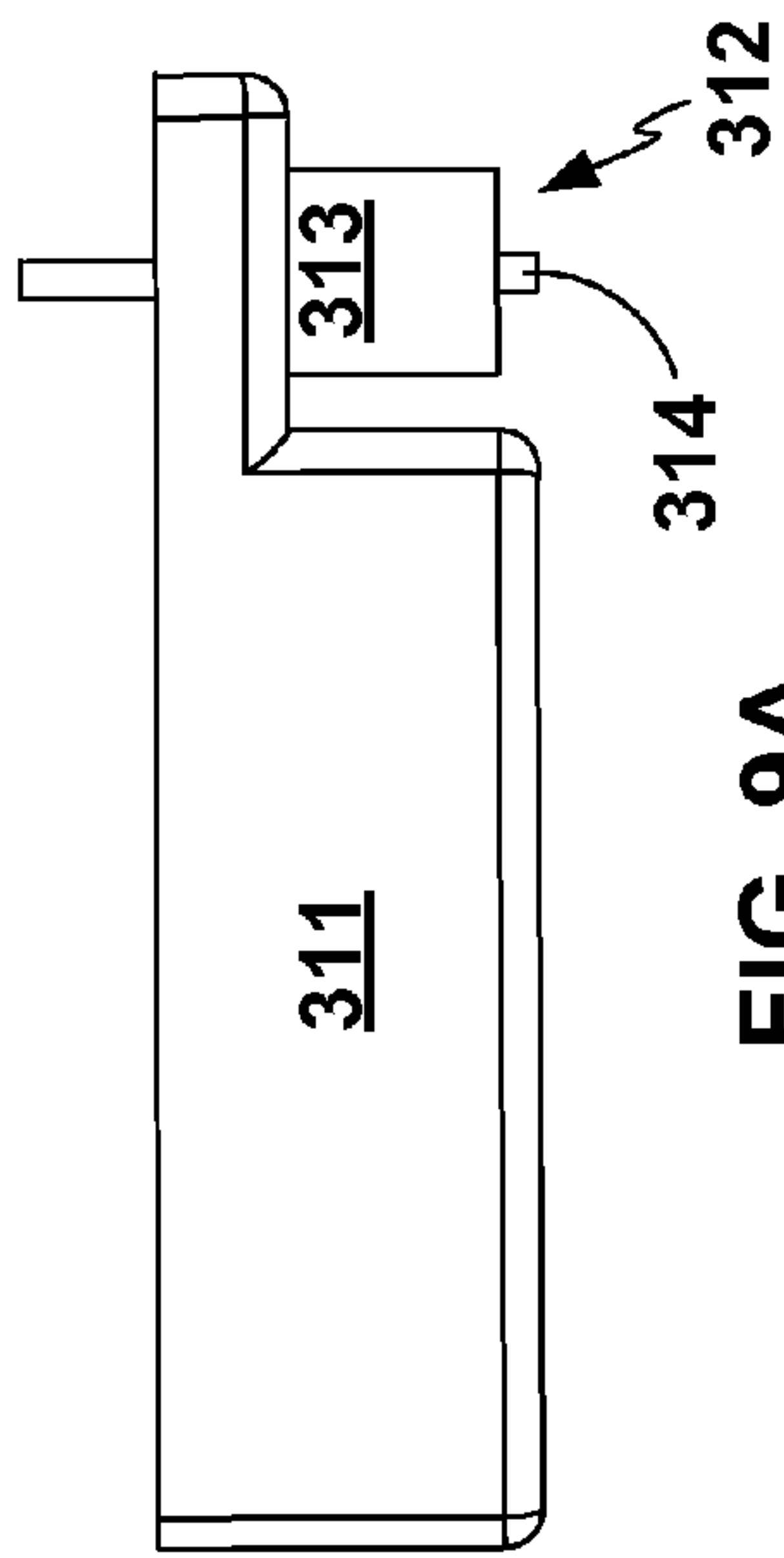


FIG. 9A

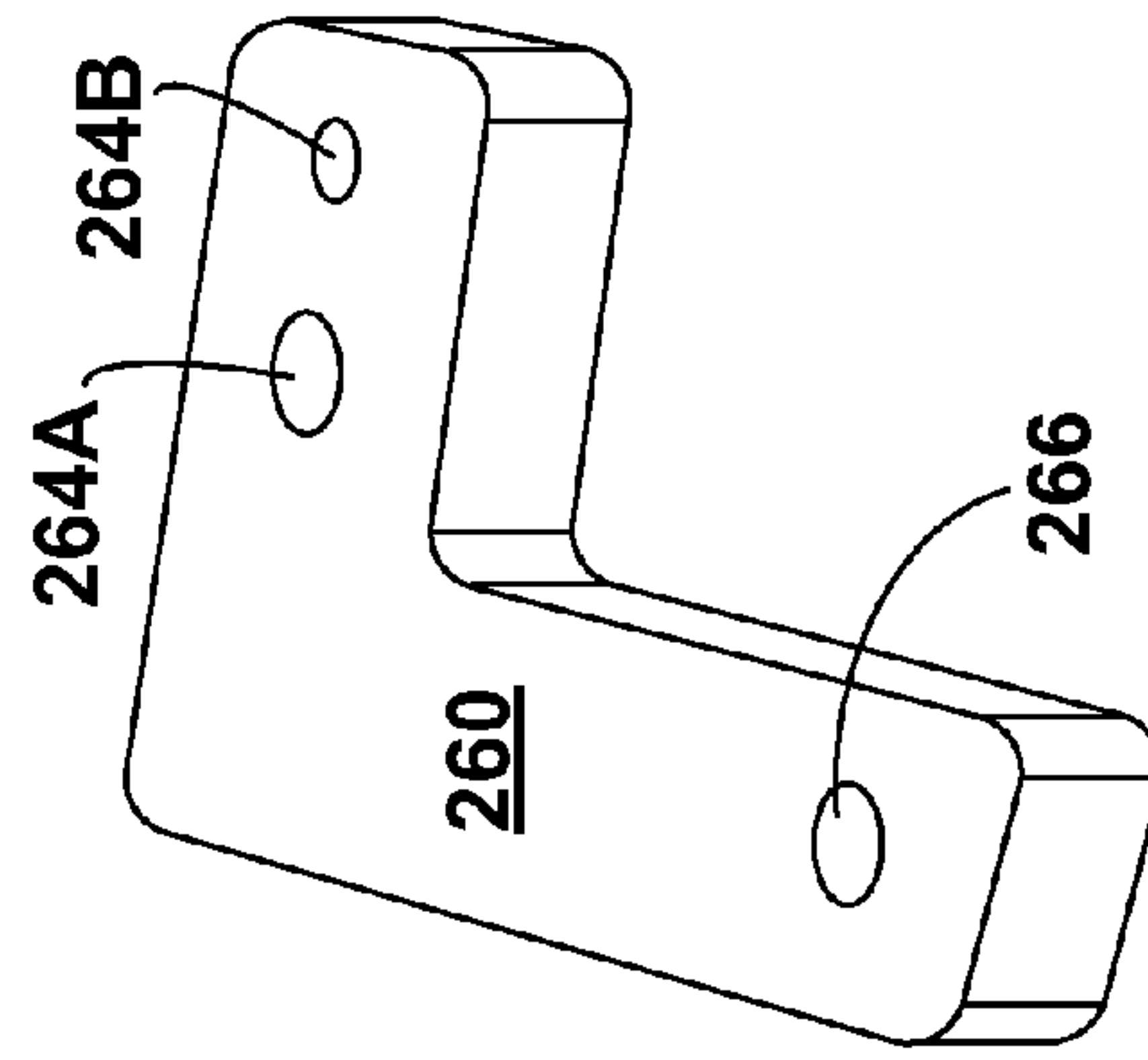


FIG. 10

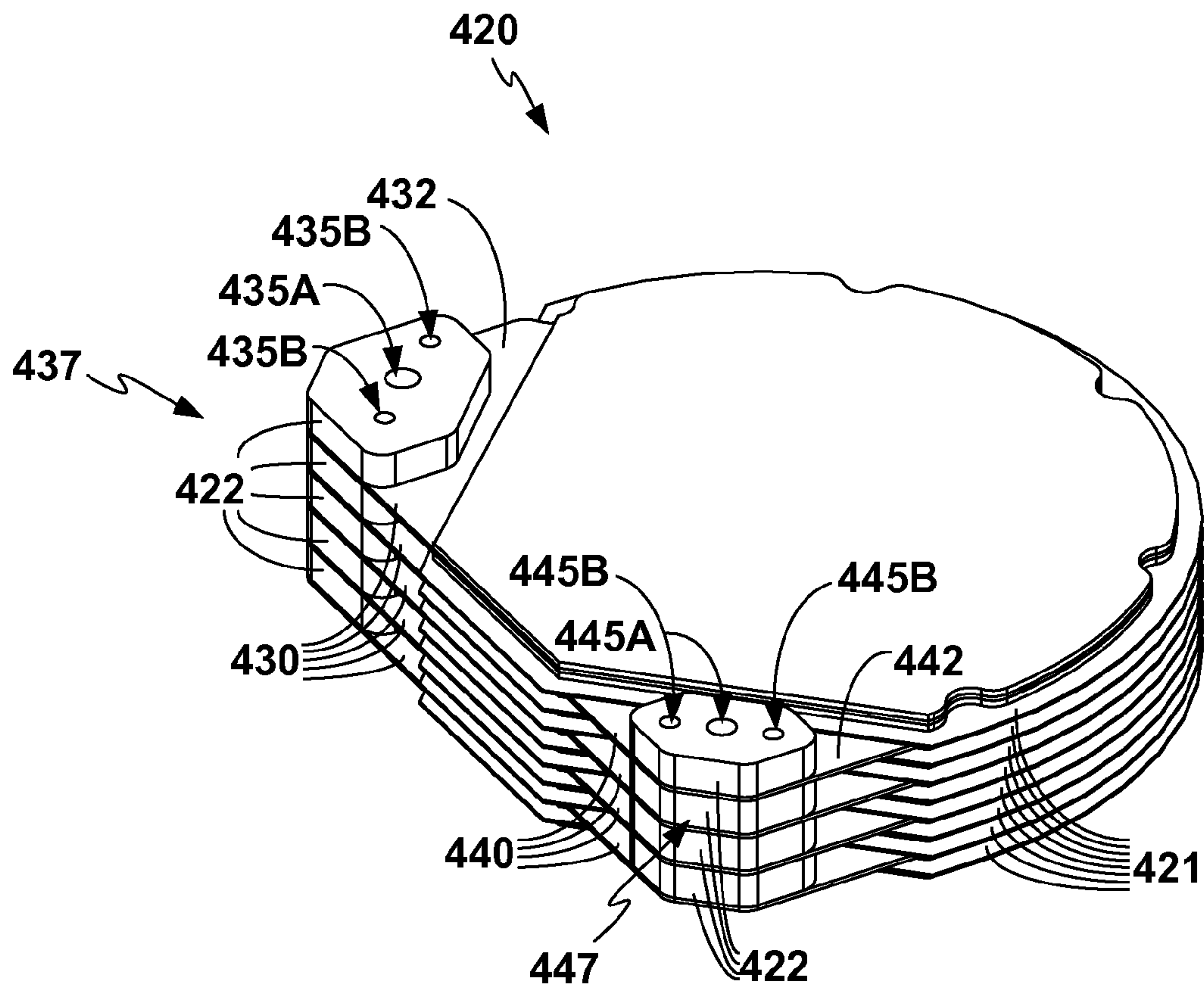


FIG. 11

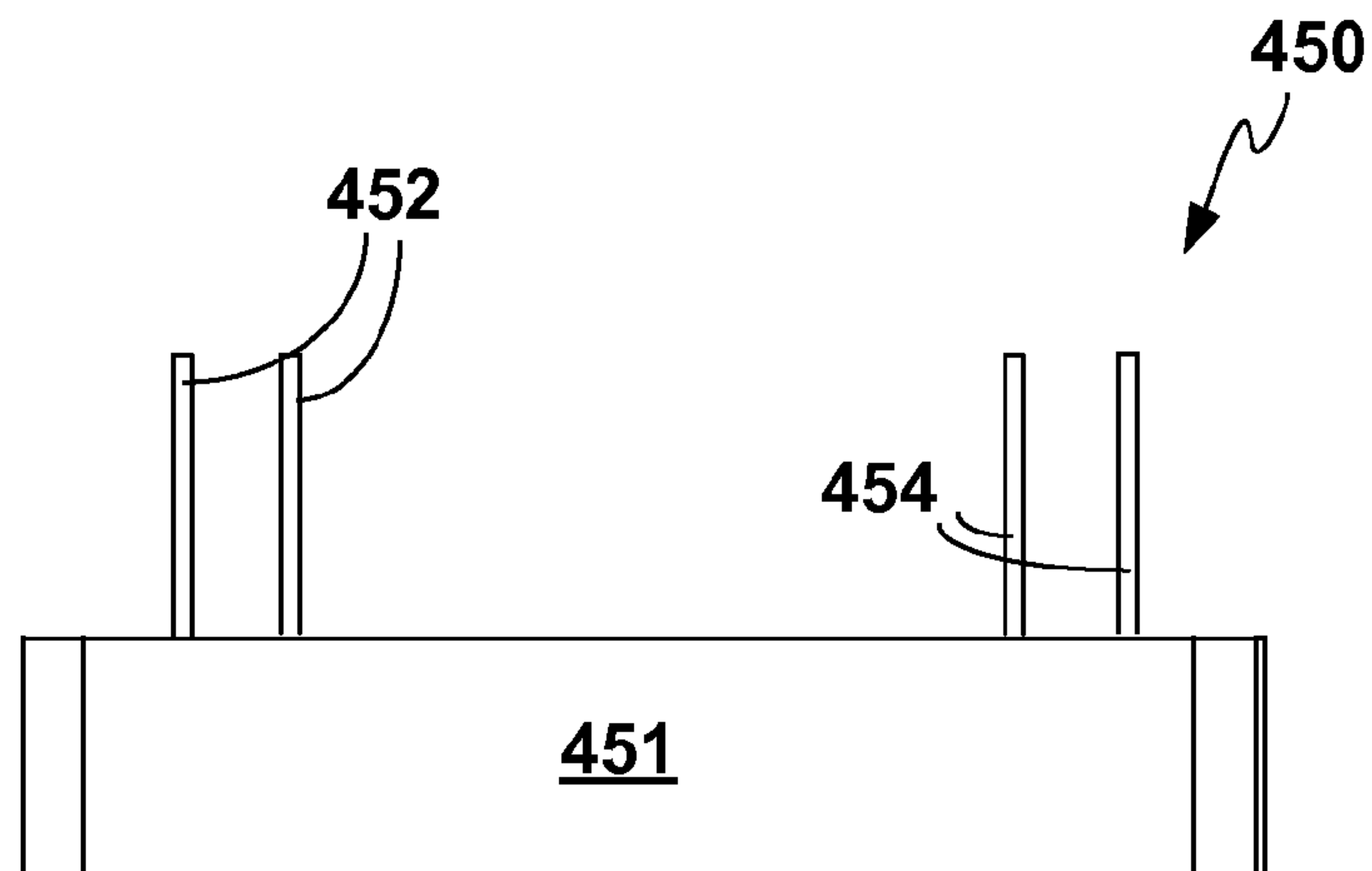


FIG. 12

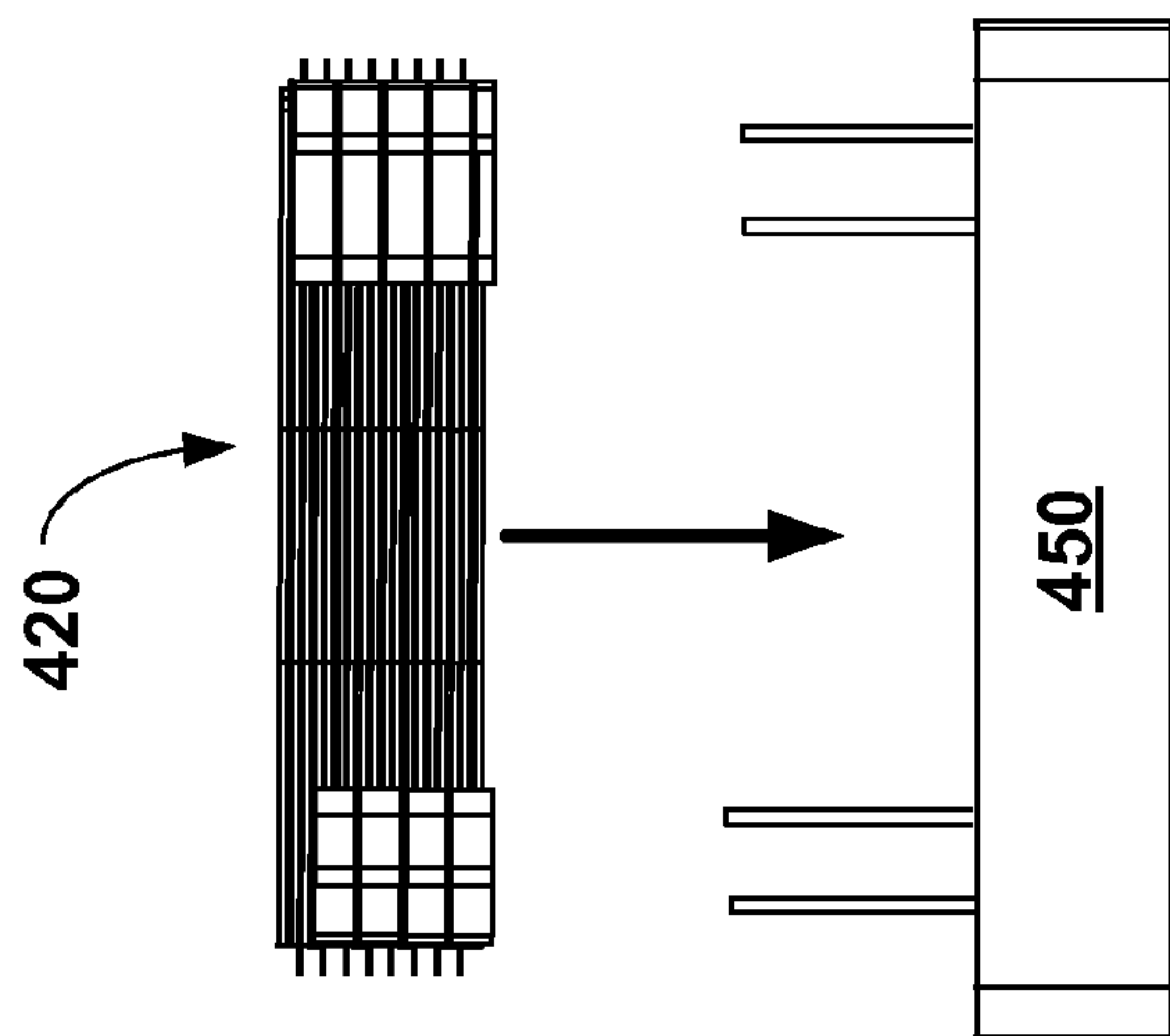


FIG. 13A

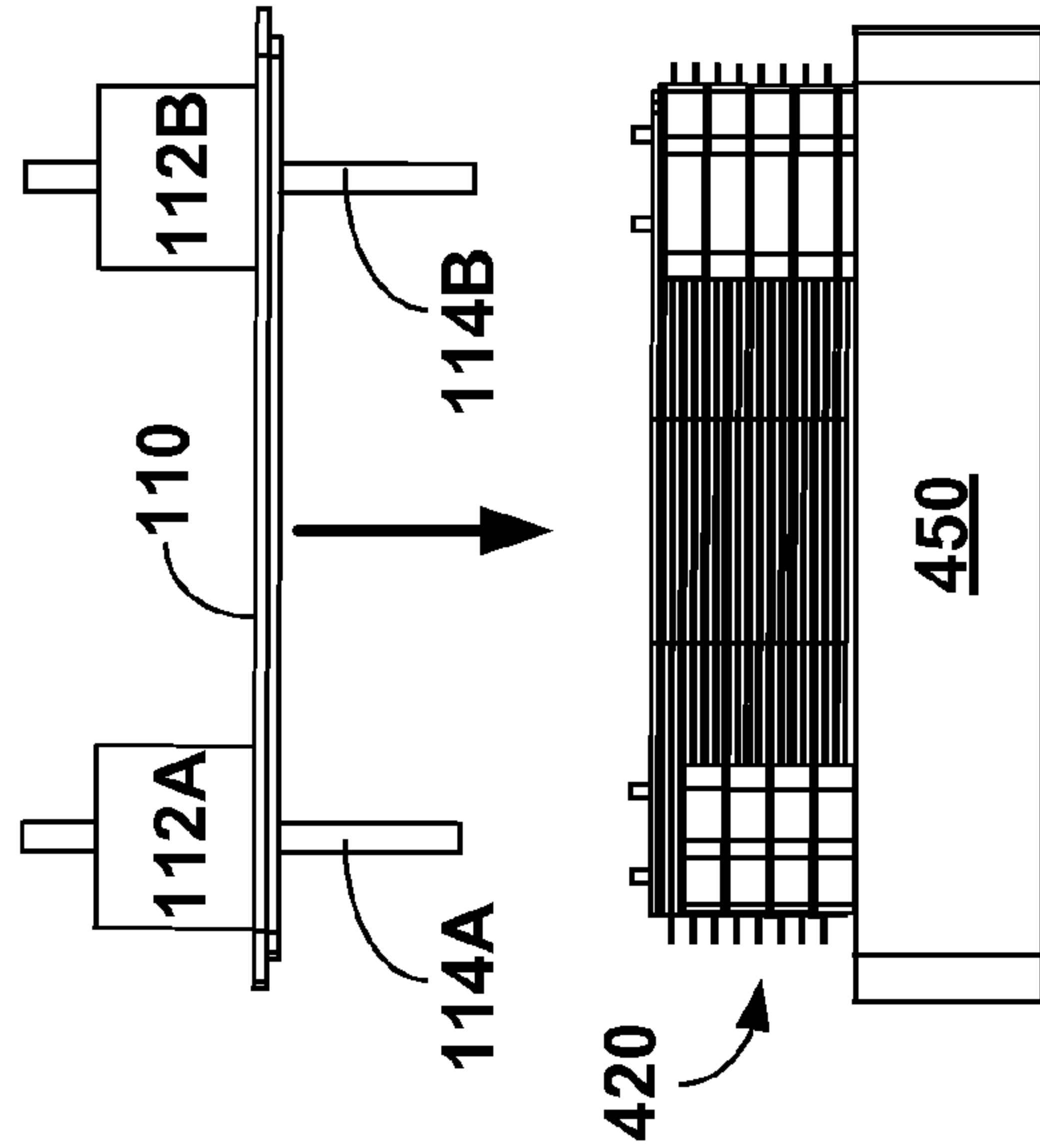


FIG. 13B

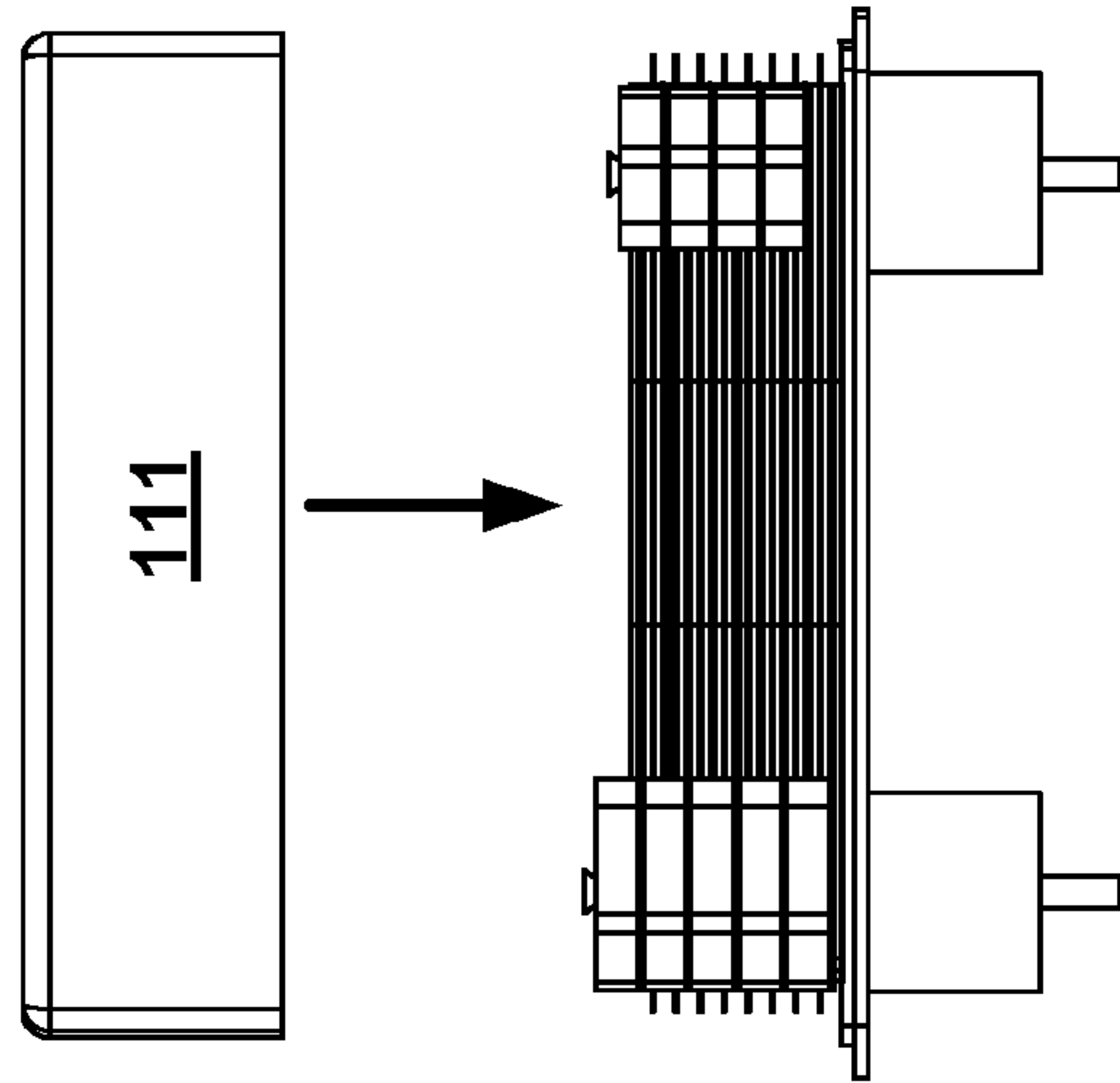


FIG. 13C

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**ELECTROCHEMICAL CELL WITH A
DIRECT CONNECTION BETWEEN A
FEEDTHROUGH PIN AND AN ELECTRODE
STACK**

TECHNICAL FIELD

This disclosure generally relates to electrochemical cells, and more particularly, but without limitation, to electrochemical cells for use in implantable medical devices.

BACKGROUND

Implantable medical devices (IMDs) may perform a variety of functions, including patient monitoring and therapy delivery. In general, it is desirable to design an IMD to be as small as possible, e.g., in terms of volume, footprint, and/or thickness, while still effectively performing its intended function. For example, decreasing the size of an IMD can increase the number of possible locations in which the IMD can be practically implanted. In addition, a smaller IMD can limit the extensiveness of surgery, reduce the likelihood of infection or rejection of the implant, and improve the comfort, and in some cases cosmetic appearance, of a patient after implantation. In other words, a smaller IMD may be more clinically acceptable than a larger IMD.

Examples of IMDs include implantable pulse generators (IPGs) and implantable cardioverter-defibrillators (ICDs). IPGs and ICDs comprise, among other things, a control module, a capacitor, and a battery that are housed in a hermetically sealed container. The battery includes a case, a liner, an electrode assembly, electrolyte, and at least one feedthrough extending through the case that serves as a battery terminal. The liner insulates the electrode assembly from the case. The electrode assembly includes electrodes, an anode and a cathode, with a separator therebetween.

SUMMARY

This disclosure includes electrochemical cells such as a battery in an implantable medical device (IMD). In one example, the battery includes an electrode assembly that comprises a set of plate electrodes. Each plate electrode includes a current collector with a tab extending therefrom and electrode material (also referred to as active material) disposed over the current collector. The battery may include spacers placed between adjacent tabs. The spacers ensure that tabs are not bent when a set of tabs are connected during a subassembly process. The tabs and the spacers may form coincident apertures to receive a feedthrough pin of a feedthrough assembly of the battery.

This disclosure further includes techniques for decreasing the volume and thickness of a battery that includes an electrode stack within an enclosure formed by a battery case. In particular, the disclosure includes techniques for reducing the space within the enclosure taken up to provide a connection between at least one feedthrough pin and the electrode stack. The described techniques include locating the feedthrough pin within coincident apertures in the conductive tabs to connect the feedthrough pin directly to the electrodes in the electrode stack.

In one example, this disclosure is directed to a battery comprising: a battery case forming a substantially sealed enclosure; an electrode stack within the enclosure, the electrode stack including a first set of electrode elements and a second set of electrode elements, the electrode elements in the second set alternating with the electrode elements in the first

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set within the electrode stack. The first set of electrode elements combine with the second set of electrode elements to form at least one voltaic cell. The battery further comprises: a first set of conductive tabs including a respective conductive tab that extends from each of the electrode elements in the first set, wherein each of the conductive tabs in the first set forms an aperture, wherein the apertures are coincident with each other; a second set of conductive tabs including a respective conductive tab that extends from each of the electrode elements in the second set; and a feedthrough including a feedthrough pin extending through the battery case and through each of the coincident apertures. The feedthrough pin serves as a positive terminal for the battery.

In another example, this disclosure is directed to a method of assembling a battery including an electrode stack for comprising: providing a first set of plate electrodes, a second set of plate electrodes, a first set of spacers and a second set of spacers. The conductive tabs in the first set of plate electrodes and the first set of spacers each include holes to facilitate alignment of the first set of plate electrodes to form a first coincident aperture that extends through the first set of plate electrodes and the first set of spacers. The conductive tabs in the second set of plate electrodes and the second set of spacers each include holes to facilitate alignment of the second set of plate electrodes to form a second coincident aperture that extends through the second set of plate electrodes and the second set of spacers. The method further comprises providing an alignment fixture including a platform and a first alignment pin and a second alignment pin. The first alignment pin and the second alignment pin extend in a common direction from the platform. The method further comprises positioning the first set of plate electrodes and the second set of plate electrodes on the alignment fixture to form the electrode stack such that the plate electrodes in the second set alternate with the plate electrodes in the first set within the electrode stack. Positioning the first set of plate electrodes and the second set of plate electrodes on the alignment fixture includes positioning the holes of the conductive tabs in the first set of plate electrodes over the first alignment pin and positioning the holes of the conductive tabs in the first set of plate electrodes over the second alignment pin. The method further comprises positioning spacers in the first set of spacers over the first alignment pin and between each adjacent conductive tab in the first set of plate electrodes when positioning the first set of plate electrodes on the alignment fixture; positioning spacers in the second set of spacers over the second alignment pin and between each adjacent conductive tab in the second set of plate electrodes when positioning the second set of plate electrodes on the alignment fixture; removing the electrode stack from the alignment fixture; and positioning the electrode stack within a battery case such that a first feedthrough pin extends through the first coincident aperture and a second feedthrough pin extends through the second coincident aperture.

In another example, this disclosure is directed to a battery comprising: a battery case forming a substantially sealed enclosure; an electrode stack within the enclosure, the electrode stack including a first set of plate electrodes and a second set of plate electrodes, the plate electrodes in the second set alternating with the plate electrodes in the first set within the electrode stack. The first set of plate electrodes combine with the second set of plate electrodes to form at least one voltaic cell, the first set of plate electrodes forming a cathode of the voltaic cell and the second set of plate electrodes forming an anode of the voltaic cell. The plate electrodes in the first and second sets of plate electrodes each includes a conductive substrate serving as a current collector,

and an electrode material disposed over the current collector. The conductive substrate includes a conductive tab that does have the electrode material coating. The electrode stack includes a first set of one or more spacers are positioned between each adjacent tab of the conductive tabs in the first set of plate electrodes. The electrode stack further includes a second set of one or more spacers are positioned between each adjacent tab of the in the first set of plate electrodes. The conductive tabs in the first set of plate electrodes and the first set of spacers are aligned to form a first coincident aperture that extends through the first set of plate electrodes and the first set of spacers. The conductive tabs in the second set of plate electrodes and the second set of spacers are aligned to form a second coincident aperture that extends through the second set of plate electrodes and the second set of spacers. The battery further comprises a first feedthrough including a first feedthrough pin extending through the battery case and through the first coincident aperture. The first feedthrough pin serves as a positive terminal for the battery. The battery further comprises a second feedthrough including a second feedthrough pin extending through the battery case and through the second coincident aperture. The second feedthrough pin serves as a negative terminal for the battery.

The details of one or more aspects of the disclosure are set forth in the accompanying drawings and the description below. Other features, objects, and advantages will be apparent from the description and drawings, and from the claims.

BRIEF DESCRIPTION OF DRAWINGS

FIG. 1 is a cutaway perspective view of an implantable medical device (IMD) including a battery.

FIG. 2 illustrates an exploded perspective view of a battery cover and an electrode stack.

FIG. 3 illustrates a spacer of the electrode stack of FIG. 2.

FIGS. 4 and 5 illustrate anode and cathode plate electrodes of the electrode stack of FIG. 2.

FIG. 6 illustrates an alignment fixture suitable for assembling the electrode stack of FIG. 2.

FIGS. 7A-7C illustrate steps for assembling a battery including the battery cover and the electrode stack of FIG. 2.

FIGS. 8A-8C illustrate a battery including a feedthrough including a ferrule located substantially within the enclosure formed by the battery case.

FIGS. 9A-9C illustrate a battery including a feedthrough including a ferrule that does not extend beyond the thickness of the battery case.

FIG. 10 illustrates a jumper from the batteries shown in FIGS. 8A-9C.

FIG. 11 illustrates an electrode stack.

FIG. 12 illustrates an alignment fixture suitable for assembling the electrode stack of FIG. 11.

FIGS. 13A-13C illustrate steps for assembling a battery including the electrode stack of FIG. 11 using the alignment fixture of FIG. 12.

DETAILED DESCRIPTION

FIG. 1 depicts an IMD 100, which may be an implantable pulse generator (IPG, e.g., a pacemaker, or an implantable cardioverter-defibrillator (ICD, as examples. IMD 100 includes a case 102, a control module 104, a battery 106 and capacitor(s) 108. Control module 104 controls one or more sensing and/or stimulation functions of IMD 100, which functions may be performed via leads 109. Battery 106 charges capacitor(s) 108 and powers control module 104.

FIGS. 2-5 and 7A-7C illustrate components of battery 106. In particular, FIG. 2 illustrates an exploded perspective view of battery cover 110 and electrode stack 120. FIG. 3 illustrates one of the spacers 122 of electrode stack 120, while FIG. 4 illustrates an anode plate electrode 130 of electrode stack 120, and FIG. 5 illustrates a cathode plate electrode 140 of electrode stack 120. The anode plate electrodes 130 and cathode plate electrodes 140 are the electrode elements of battery 106. In some examples, anode plate electrodes 130 and cathode plate electrodes 140 may be substantially planar, in other examples, anode plate electrodes 130 and cathode plate electrodes 140 may be curved along one or more axis.

Battery 106 includes a battery case forming a substantially sealed enclosure with casement 111 (FIG. 7B) and top cover 110. As shown in FIG. 2, feedthroughs 112A and 112B (“feedthroughs 112”) extend through top cover 110 and each include one of ferrules 113A, 113B (“ferrules 113”), one of feedthrough pins 114A, 114B (“feedthrough pins 114”) and one of insulators 115A, 115B (“insulators 115”). In some examples, feedthrough pins 114 have diameters of less than 0.050 inches, such as a diameter of no greater than about 0.030 inches, such as a diameter of about 0.021 inches or a diameter of about 0.012 inches. Battery 106 further includes electrode stack 120, which is within the enclosure formed by the battery case. In some examples, battery 106 includes a fill port (not shown) as well as a liquid electrolyte within the enclosure. In some examples, battery 106 may be an organic electrolyte battery 106.

Electrode stack 120 includes a first set of plate electrodes 130 and a second set of plate electrodes 140. Positioned between each adjacent plate electrode 130 and plate electrode 140 is one of separators 121. Plate electrodes 130 form the cathode of battery 106, whereas plate electrodes 140 form the anode of battery 106 such that plate electrodes 130 combine with plate electrodes 140 to form a voltaic cell. Plate electrodes 130 alternate with plate electrodes 140 within electrode stack 120.

Each of plate electrodes 130 and plate electrodes 140 includes an electrically conductive substrate serving as a current collector. The electrically conductive substrate may be made of a metal, such alloys of copper, titanium, aluminum etc. As an example, the conductive substrate of the top plate electrode 130 is represented by reference numeral 131 in FIG. 2. An electrode material is disposed over the current collector in each of plate electrodes 130 and plate electrodes 140. As an example, the electrode material of the top plate electrode 130 is represented by reference numerals 133 in FIG. 2. In battery 106, the conductive substrates are substantially flat, and may include holes or other features to facilitate adhesion between the conductive substrate and the electrode material.

Each anode plate electrode 130 includes a current collector, such as current collector 131, a tab 132 extending there from, and electrode material disposed over the current collector. Tab 132 comprises conductive material (e.g. copper, titanium, aluminum etc.). In some examples, the current collector may be a unitary component with a tab 132. The electrode material, such as electrode material 133, includes elements from Group IA, IIA or IIIB of the periodic table of elements (e.g. lithium, sodium, potassium, etc.), alloys thereof, intermetallic compounds (e.g. Li—Si, Li—B, Li—Si—B etc.), or an alkali metal (e.g. lithium, etc.) in metallic form. In a further example, such as with a rechargeable cell, the electrode material of the anode plate electrode 130 may be lithium cobalt oxide or other suitable electrode material. The conductive substrate of anode plate electrode 130 may comprise nickel, titanium, copper an alloy thereof or other suitable conductive material. In some examples, a sepa-

rator **121** may be coupled to the electrode material at the top and bottom of anode plate electrodes **130**.

Each cathode plate electrode **140** is constructed in a similar manner as the anode plate electrodes **130**. A cathode plate electrode **140** includes a conductive substrate serving as a current collector, a tab **142** (FIG. 5) extending there from and an electrode material disposed over the current collector. In some examples, the current collector may be a unitary component with a tab **142**. The electrode material of the cathode plate electrodes **140** includes metal oxides (e.g. vanadium oxide, silver vanadium oxide (SVO), manganese dioxide etc.), carbon monofluoride and hybrids thereof (e.g., $CF_x + MnO_2$), combination silver vanadium oxide (CSVO), lithium ion, other rechargeable chemistries, or other suitable compounds. In a further example, such as with a rechargeable cell, the electrode material of the cathode plate electrode **140** may be lithium titanate, graphite or other suitable electrode material. The conductive substrate of cathode plate electrode **140** may be, for example, titanium, aluminum, nickel or other suitable materials.

While the example chemistries provided. Our current chemistries are lithium cobalt oxide for the positive and either lithium titanate or graphite for the negative.

As previously mentioned, each anode plate electrode **130** includes a tab **132**. A spacer **122** is positioned between each adjacent tab **132**. Similarly, each cathode plate electrode **140** includes a tab **142**, and a spacer **122** is positioned between each adjacent tab **142**. Spacers **122** function to mitigate bending of tabs **132** and **142** during assembly of electrode stack **120**. Spacers **122** may also be formed from a conductive material such as titanium, aluminum/titanium clad metal or other suitable materials. Accordingly, spacers **122** may also serve to electrically connect anode plate electrodes **130** via tabs **132** with each other as well as electrically connect cathode plate electrodes **140** via tabs **142** with each other within electrode stack **120**.

As previously mentioned, tabs **132**, **142** may be a unitary component with the electrically conductive substrates of anode plate electrode **130** and cathode plate electrode **140** respectively. In one example, tabs **132** may be formed by masking a portion of an electrically conductive substrate when depositing an electrode material, e.g., lithium, on the electrically conductive substrate of a plate electrode. The electrically conductive substrate may be masked by placing a material, such as a polymer between electrically conductive substrates and the electrode material. In some examples, the mask material may be die cut to provide precise masking of tabs **132** and **142**.

The thickness of spacers **122** is dependent on the thicknesses of anode plate electrode **130** and cathode plate electrode **140**. As an example, spacers **122** may have a thickness of less than 0.060 inches, such as a thickness of about 0.020 inches. In other examples, spacers **122** may have a thickness of between 0.10 inches to 0.060 inches. In a further example, such as in a rechargeable cell, spacers **122** may have a thickness of between 0.005 inches to 0.020 inches. For example, the electrode material of rechargeable cells may be formed using a slurry process, which can provide thinner electrode plates than with a pressed powder process more commonly used for making electrode plate in nonrechargeable cells. In general, the thickness of spacers should be selected to match the spacing between adjacent tabs **132** and adjacent tabs **142** when anode plate electrodes **130** and cathode plate electrodes **140** are stacked, e.g., directly on each other.

Further details and techniques suitable for the construction of electrode stack **120** are disclosed in United States Patent Publication Number 2009/0197180 by Viavattine et al., titled

“SPACERS BETWEEN TABS OF PLATE ELECTRODES IN AN ELECTROCHEMICAL CELL FOR AN IMPLANTABLE MEDICAL DEVICE,” the entire content of which is incorporated by reference herein.

As illustrated in FIG. 3, spacers **122** include alignment apertures **124A** and **124B**. In the set of spacers **122** between adjacent tabs **132**, alignment apertures **124A** are coincident with each other and with alignment apertures **134A** (FIG. 4) of tabs **132** to form coincident aperture **135A** (FIG. 2). Likewise, alignment apertures **124B** are coincident with each other and with alignment apertures **134B** of tabs **132** to form coincident aperture **135B**. As shown in FIG. 7B, feedthrough pin **114A** extends through the battery case and through incident aperture **135A** and serves as a positive terminal for battery **106**.

Similarly, in the set of spacers **122** between adjacent tabs **142**, alignment apertures **124A** are coincident with each other and with alignment apertures **144A** of tabs **142** to form coincident aperture **145A**. Likewise, alignment apertures **124B** are coincident with each other and with alignment apertures **144B** of tabs **142** to form coincident aperture **145B**. Feedthrough pin **114B** extends through the battery case and through incident aperture **145A** and serves as a negative terminal for battery **106**. In other examples, a battery may not include a distinct negative battery terminal and case of the battery may serve as the negative battery terminal.

Connecting feedthrough pins **114** directly to tabs **132** and **134** of plate electrodes **130** and **140** respectively provides for robust electrical connections between feedthrough pins **114** and plate electrodes **130** and **140**. In addition connecting feedthrough pins **114** directly to tabs **132** and **134** of plate electrodes **130** and **140** respectively also serves to minimize the space in battery **106** required for feedthroughs **112** as well as limit heat generation caused by electrical resistance in the electrical connection between feedthrough pins **114** and plate electrodes **130** and **140**. The design of tabs **132** and **142** also serves to limit electrical resistance in the electrical connection between feedthrough pins **114** and plate electrodes **130** and **140** because tabs **132** and **142** provide a wide electrical path between feedthrough pins **114** and plate electrodes **130** and **140** respectively.

FIG. 6 illustrates an example alignment fixture **150**, which is suitable for stacking and aligning components of electrode stack **120** during assembly. Each anode plate electrode **130**, cathode plate electrode **140** and spacer **122** in electrode stack **120** includes alignment apertures to facilitate stacking the components of electrode stack **120** in alignment on alignment fixture **150**. Alignment fixture **150** includes platform **151** and alignment pins **152A**, **152B**, **154A** and **154B**, each extending in a common direction from platform **151**. Alignment pins **152A**, **152B** (“alignment pins **152**”) serve as mating protrusions for coincident apertures **135A** and **135B**, including alignment apertures **134** in anode plate electrodes **130** as well as alignment apertures **124** in the spacers **122** positioned between adjacent tabs **132**. Likewise, alignment pins **154A**, **154B** (“alignment pins **154**”) serve as mating protrusions for coincident apertures **145A** and **145B**, including alignment apertures **144** in cathode plate electrodes **140** as well as alignment apertures **124** in the spacers **122** positioned between adjacent tabs **142**.

During the assembly process of electrode stack **120**, the components of electrode stack **120**, including each anode plate electrodes **130**, cathode plate electrode **140** and spacer **122** are positioned over alignment pins **152** and **154** and stacked on alignment fixture **150**. Anode plate electrodes **130** alternate with cathode plate electrode **140** when stacked on alignment fixture **150**. Plate electrodes are stacked on align-

ment fixture **150** such that alignment apertures **134** of anode plate electrodes **130** are positioned over alignment pins **152**, and alignment apertures **144** of cathode plate electrodes **140** are positioned over alignment pins **154**. Spacers **122** positioned between adjacent tabs **132** on alignment pins **152** and between adjacent tabs **142** on alignment pins **154**.

Alignment pins **152** facilitate proper alignment of anode plate electrodes **130** by interacting with alignment apertures **134** in anode plate electrodes **130** to restrict rotation of anode plate electrodes **130** to align anode plate electrodes **130** as well as the spacers **122** positioned between adjacent tabs **132** with each other. Similarly, alignment pins **154** facilitate proper alignment of cathode plate electrodes **140** by interacting with alignment apertures **144** in cathode plate electrodes **140** to restrict rotation of cathode plate electrodes **140** to align cathode plate electrodes **140** as well as the spacers **122** positioned between adjacent tabs **142** with each other.

Alignment apertures **134** in anode plate electrodes **130** are orientated differently alignment apertures **144** in cathode plate electrodes **140**. In particular, alignment apertures **134** in anode plate electrodes **130** are orientated differently than alignment apertures **144** in cathode plate electrodes **140** to prevent interchanging an anode plate electrodes **130** with a cathode plate electrodes **140** within the electrode stack **120** during assembly of the electrode stack **120** on alignment fixture **150** and vice versa. Simply, an anode plate electrode **130** will not fit in the place of cathode plate electrode **140** on alignment fixture **150**. However, the configurations of alignment apertures **134** and alignment apertures **144** is similar in that the same spacer **122** may be used in between adjacent tabs **132** and in between adjacent tabs **142** on alignment fixture **150**. In particular, a spacer **122** positioned over alignment pins **152** (suitable for placement in-between adjacent tabs **132**) merely needs to be rotated to positioned over alignment pins **154** (suitable for placement in-between adjacent tabs **142**).

Once the components of electrode stack **120** including each anode plate electrode **130**, cathode plate electrode **140** and spacer **122** are positioned appropriately on alignment fixture **150** to form electrode stack **120**, tabs **132** and spacers **122** adjacent tabs **132** may be welded to each other with a single weld, such as a laser weld to form a weld joint in weld zone **137** (FIG. 2), a beveled corner of electrode stack **120**. Likewise, tabs **142** and spacers **122** adjacent tabs **142** may also be welded to each other with one additional to form a weld joint in weld zone **147**. In some examples, laser welding may occur while the components of electrode stack **120** remain on alignment fixture **150**. In other examples, the relative alignment of the components of electrode stack **120** provided by alignment fixture **150** may be maintained during welding even though the components of electrode stack **120** may be removed from alignment fixture **150** prior to welding operations.

FIGS. 7A-7C illustrate steps for assembling battery **106**. The steps for assembling battery **106** may be automated, e.g., using pick-and-place machinery, performed manually, or performed with a combination of automated and manual steps. As discussed above, the components of electrode stack **120** are stacked and aligned, e.g., using an alignment fixture such as alignment fixture **150**. The components of electrode stack **120** may also be connected using welds, e.g., by laser welding in weld zones **137** and **147**, either on an alignment fixture or after removing the components of electrode stack **120** from the alignment fixture, but while maintaining the relative alignment provided by the alignment fixture. In some examples, an insulator may be placed over electrode stack **120** while the components of electrode stack **120** remain on

the alignment fixture. The insulator serves to electrically isolate the electrode stack from the battery case once battery **106** is assembled. An exemplary insulator is shown as insulator **223** in FIG. 8A.

As shown in FIG. 7A, cover **110** includes feedthroughs **112** extending there through. Electrode stack **120** is positioned over cover **110** and slid over feedthrough pins **114** such that pin **114A** extends through coincident aperture **135A** in tabs **132**, and pin **114B** extends through coincident aperture **145A** in tabs **142**. The end of feedthrough pin **114A** may be welded to electrode stack **120** opposite coincident aperture **135A**, and the end of feedthrough pin **114B** may be welded to electrode stack **120** opposite coincident aperture **145A**. For example, spot welding may be used to electrically and mechanically couple feedthrough pins **114** to electrode stack **120**. Alternatively or in addition to spot welding, the ends of feedthrough pins **114** may be crimped to secure feedthrough pins **114** to electrode stack **120**. In some examples, welding in weld zones **137** and **147** may occur only after placing the components electrode stack **120** over feedthrough pins **114** such that welding in weld zones **137** and **147** may occur at the same time as the welding of feedthrough pins **114** to electrode stack **120**.

As shown in FIG. 7B, once electrode stack **120** is secured to cover **110**, casement **111** is positioned over electrode stack **120**. As shown in FIG. 7C, the interface between cover **110** and casement **111** may then be welded to provide battery **106** with a substantially sealed enclosure including electrode stack **120**. In some examples, battery **106** may also include a fill port (not shown) and liquid electrolyte may then be added to battery **106** via the fill port.

FIGS. 8A-8C illustrate components of battery **206**. Battery **206** is similar to battery **106**. For brevity, features of battery **206** that are substantially similar to features previously discussed with respect to battery **106** are discussed in limited or no detail with respect to battery **206**. Battery **206** includes electrode stack **220** and a case including cover **210** and casement **211**. Cover **210** and casement **211** combine to form a substantially sealed enclosure containing electrode stack **220**.

Battery **206** further includes feedthrough **212**, which serves as a positive terminal of battery **206**. Feedthrough **212** extends through cover **210**, which is substantially flat. Feedthrough **212** includes ferrule **213**, feedthrough pin **214** and insulator **215**, which electrically isolates feedthrough pin **214** from ferrule **213**. A majority of ferrule **213** is located within the enclosure of battery **206**, for example, ferrule **213** may be located substantially within the enclosure of battery **206**. The configuration of battery **206** allows feedthrough **212** to extend in a direction parallel to the thickness dimension of battery **206** without extending significantly beyond the thickness of battery **206**. This allows battery **206** to provide a thinner overall provide than battery **106**. However, the configuration of battery **206** may provide a lower overall energy density than that of battery **106** because of the space required within the enclosure of battery **206** for jumper **260**.

Electrode stack **220** is substantially similar to electrode stack **120** except that electrode stack **220** connects to the positive terminal of battery **206** via jumper **260**. For example, electrode stack **220** includes anode plate electrodes that alternate with cathode plate electrodes within electrode stack **220** with separators between adjacent anode plate electrodes and cathode plate electrodes. Electrode stack **220** also includes spacers between tabs of the plate electrodes and coincident alignment apertures to facilitate alignment of anode plate electrodes, cathode plate electrodes and spacers on an alignment fixture such as alignment fixture **150**.

Jumper **260** is in electrical contact with the anode of electrode stack **220** as well as feedthrough pin **214**, which serves

as the positive terminal of battery 206. Battery 206 does not include a distinct negative terminal; instead, electrode stack 120 is electrically coupled to cover 210 (not shown), such that the case of battery 206 serves as the negative terminal of battery 206 (also referred to as case negative).

Details of jumper 260 are illustrated in FIG. 10. Jumper 260 includes alignment apertures 264A and 264B (“alignment apertures 264”). Within electrode stack 220, alignment apertures 264 align with coincident alignment apertures within tabs of anode plate electrodes of electrode stack 220. Alignment apertures 264 are configured to restrict rotation of jumper 260 and locate jumper 260 relative to the electrode stack 220 when alignment apertures 264 are positioned over mating alignment protrusions, e.g., such as alignment protrusions 152, during assembly of electrode stack 220. For example, jumper 260 may be located on an alignment fixture, such as alignment fixture 150, with the components of electrode stack 220.

Jumper 260 may be formed from a conductive material such as titanium, aluminum/titanium clad metal or other suitable materials. Jumper 260 may be secured to tabs of anode plate electrodes of electrode stack 220 during the assembly process of electrode stack 220. For example, jumper 260 may be secured to tabs of anode plate electrodes of electrode stack 220 during a welding operation to secure the tabs of anode plate electrodes of electrode stack 220 to each other.

The configuration of jumper 260 facilitates customizable placement of feedthrough 212 on the battery case without altering the components of electrode stack 220. For example, the same electrode stack 220 may be used with multiple jumper configurations to locate a feedthrough at different positions on a battery case. Such configurability may be useful to reduce the size and/or cost of implantable medical devices including a battery such as battery 206 by optimizing the placement of the feedthrough according to the configuration of other components within an implantable medical device. While battery 206 only includes a single feedthrough and a single jumper, the same techniques discussed with respect to jumper 260 and feedthrough 212 may be used to provide a second feedthrough serving as a negative terminal for battery 206.

FIGS. 8A-8C illustrate steps for assembling battery 206. The steps for assembling battery 206 may be automated, e.g., using pick-and-place machinery, performed manually, or performed with a combination of automated and manual steps. First, the components of electrode stack 220 are stacked and aligned in combination with jumper 260, e.g., using an alignment fixture such as alignment fixture 150. The components of electrode stack 120 as well as jumper 260 may also be connected using welds, e.g., by laser welding either on an alignment fixture.

Cover 210 includes feedthrough 212 extending there through. Insulator 223 is located on the inside of cover 210 to electrically isolate electrode stack 220 from the battery case once battery 306 is assembled. Electrode stack 220 is positioned over cover 110 and jumper 260 slid over feedthrough pin 214 such that pin 214 extends through feedthrough pin hole 266 (FIG. 10) in jumper 260.

The end of feedthrough pin 214 may be spot welded to jumper 260 opposite feedthrough pin hole 266 (FIG. 10) to and mechanically couple feedthrough pin 214 to jumper 260. Alternatively or in addition to spot welding, the end of feedthrough pin 214 may be crimped to secure feedthrough pin 214 to jumper 260.

As shown in FIG. 8A, once jumper 260 is secured to cover 210, casement 211 is positioned over electrode stack 220 and jumper 260. As shown in FIGS. 8B and 8C, the interface

between cover 210 and casement 211 may then be welded to provide battery 206 with a substantially sealed enclosure containing electrode stack 220, jumper 260 and a majority of feedthrough 213. In some examples, battery 206 may also include a fill port (not shown) and liquid electrolyte may then be added to battery 206 via the fill port.

The case of battery 206 provides thickness 270, which is measured along the shortest dimension of the battery case. A longitudinal axis 224 of feedthrough 212 is parallel to thickness 270 and ferrule 213 of feedthrough 212 does not extend beyond the thickness 270. This allows battery 206 to provide a thinner overall profile than battery 106.

FIGS. 9A-9C illustrate components of battery 306. Battery 306 is similar to batteries 106 and 206. For brevity, features of battery 306 that are substantially similar to features previously discussed with respect to batteries 106 and 206 are discussed in limited or no detail with respect to battery 306. Battery 306 includes electrode stack 220 and a case including cover 310 and casement 311. Electrode stack 220 in battery 306 may be substantially the same as electrode stack 220 in battery 206. Cover 310 and casement 311 combine to form a substantially sealed enclosure containing electrode stack 220.

Battery 306 further includes feedthrough 312, which serves as a positive terminal of battery 306. Feedthrough 312 extends through casement 311. Feedthrough 312 includes ferrule 313, feedthrough pin 314 and insulator 315, which electrically isolates feedthrough pin 314 from ferrule 313.

The case of battery 306 provides thickness 370, which is measured along the shortest dimension of the battery case. A longitudinal axis 324 of feedthrough 312 is parallel to thickness 370 and feedthrough 312 does not extend beyond the thickness 370. This allows battery 306 to provide a thinner overall profile than battery 106. As compared to battery 206, battery 306 provides feedthrough 312 with an exposed ferrule 313, which may facilitate a more robust or simpler electrical connection between battery 306 and other electrical components within an implantable medical device.

The assembly process of battery 306 may be more difficult than the assembly process of battery 206 in that electrode stack 220 is not exposed in casement 311 once jumper 260 is secured to feedthrough pin 314. As one example, the configuration of battery 306 does not facilitate welding tabs of plate electrodes in electrode stack 220 to each other after positioning the components of electrode stack 220 in casement 311. In contrast, the configuration of battery 206 does allow welding tabs of plate electrodes in electrode stack 220 to each other after positioning the components of electrode stack 220 on cover 210. For this reason, welding jumper 260 to feedthrough pin 214 could occur at the same time as welding tabs of plate electrodes in electrode stack 220 to each other during the assembly of battery 206. In contrast, welding tabs of plate electrodes in electrode stack 220 to each other during the assembly of battery 306 should occur prior to placing electrode stack 220 in casement 111 and prior to welding jumper 260 to feedthrough pin 314.

As shown in FIG. 9B, once jumper 260 is secured to casement 311, cover 310 is positioned over electrode stack 220 and jumper 260. As shown in FIGS. 9B and 9C, the interface between cover 310 and casement 311 may then be welded to provide battery 306 with a substantially sealed enclosure containing electrode stack 220 and jumper 260. In some examples, battery 306 may also include a fill port (not shown) and liquid electrolyte may then be added to battery 306 via the fill port.

FIG. 11 illustrate electrode stack 420. Electrode stack 420 is substantially similar to electrode stack 120 (FIG. 2) except that electrode stack 420 forms additional coincident apertures

435B and 445B. For brevity, details of electrode stack 420 that are the same as electrode stack 120 are discussed in limited detail with respect to electrode stack 420.

Electrode stack 420 includes a first set of plate electrodes 430 and a second set of plate electrodes 440. Positioned between each adjacent plate electrode 430 and plate electrode 440 is one of separators 421. Plate electrodes 430 form a cathode, whereas plate electrodes 440 form an anode. Each anode plate electrode 430 includes a current collector, a tab 432 extending there from, and electrode material disposed over the current collector. Each anode plate electrode 440 includes a current collector, a tab 442 extending there from, and electrode material disposed over the current collector. Plate electrodes 430 alternate with plate electrodes 440 within electrode stack 420.

Like spacers 122 in electrode stack 120, a spacer 422 is positioned between each adjacent tab 132 and 142. Spacers 422 function to mitigate bending of tabs 432 and 442 during assembly of electrode stack 420 as well as provide electrical connections between adjacent tabs.

The set of spacers 422 between adjacent tabs 432 provide alignment apertures that are coincident with alignment apertures of tabs 132 to form coincident apertures 435A and 435B. Likewise, the set of spacers 422 between adjacent tabs 442 provide alignment apertures that are coincident with alignment apertures of tabs 142 to form coincident apertures 445A and 445B. Coincident apertures 435A and 445A are each configured to receive a feedthrough pin, such as feedthrough pins 113A and 113B, whereas coincident apertures 435B and 445B are configured to receive alignment pins on an alignment fixture during the assembly of electrode stack 420.

FIG. 12 illustrates alignment fixture 450, which is suitable for stacking and aligning components of electrode stack 420. Each anode plate electrode 430, cathode plate electrode 440 and spacer 422 in electrode stack 420 includes alignment apertures to facilitate stacking the components of electrode stack 420 in alignment on alignment fixture 450. Alignment fixture 450 includes platform 451 and alignment pins 452 and 454, each extending in a common direction from platform 451. Alignment pins 452 serve as mating protrusions for coincident apertures 435B. Likewise, alignment pins 454 serve as mating protrusions for coincident apertures 445B.

During the assembly process of electrode stack 420, the components of electrode stack 420, including each anode plate electrodes 430, cathode plate electrode 440 and spacers 422 are positioned over alignment pins 152 and 154 and stacked on alignment fixture 150. Anode plate electrodes 430 alternate with cathode plate electrode 440 when stacked on alignment fixture 450. Plate electrodes are stacked on alignment fixture 450 such that alignment apertures of anode plate electrodes 430 are positioned over alignment pins 452, and alignment apertures of cathode plate electrodes 440 are positioned over alignment pins 454. Spacers 422 positioned between adjacent tabs 432 on alignment pins 452 and between adjacent tabs 442 on alignment pins 454.

Alignment pins 452 facilitate proper alignment of anode plate electrodes 430 by interacting with alignment apertures in anode plate electrodes 430 to restrict rotation of anode plate electrodes 430 to align anode plate electrodes 430 as well as the spacers 422 positioned between adjacent tabs 432 with each other. Similarly, alignment pins 454 facilitate proper alignment of cathode plate electrodes 440 by interacting with alignment apertures 444 in cathode plate electrodes 440 to restrict rotation of cathode plate electrodes 440 to align cathode plate electrodes 440 as well as the spacers 422 positioned between adjacent tabs 442 with each other.

The alignment apertures in anode plate electrodes 430 may be orientated differently than alignment apertures in cathode plate electrodes 440 to prevent interchanging an anode plate electrode 430 with a cathode plate electrode 440 within the electrode stack 420 during assembly of the electrode stack 420 on alignment fixture 450 and vice versa.

FIGS. 13A-13C illustrate steps for assembling a battery including electrode stack 420 using alignment fixture 450. The steps for assembling electrode stack 420 may be automated, e.g., using pick-and-place machinery, performed manually, or performed with a combination of automated and manual steps. As discussed above, the components of electrode stack 420 are stacked and aligned, e.g., using an alignment fixture such as alignment fixture 450. The components of electrode stack 420 may also be connected using welds, e.g., by laser welding in weld zones 437 and 447 (FIG. 11), on alignment fixture 450.

However, even after welding of anode plate electrodes 430 in weld zone 437 and cathode plate electrodes 440 in weld zone 447, the alignment of anode plate electrodes 430 relative to cathode plate electrodes 440 is not inherently secured without alignment fixture 450. Electrode stack 420 provides an advantage relative to electrode stack 120 in that electrode stack 420 may receive feedthrough pins 114 of feedthroughs 112 (FIG. 13B) while electrode stack 420 is still positioned on alignment stand 450. Once feedthrough pins 114 are mated to coincident apertures 435A and 445A of anode plate electrodes 430 and cathode plate electrodes 440 respectively, feedthroughs 112 and cover 110 serve to maintain the alignment of anode plate electrodes 430 relative to cathode plate electrodes 440.

As shown in FIG. 13A, electrode stack 420 is first assembled using alignment fixture 450. For example, assembly of electrode stack 420 may include welding of anode plate electrodes 430 in weld zone 437 and cathode plate electrodes 440 in weld zone 447. Next, as shown in FIG. 13B cover 110 is positioned over electrode stack 420 while the components of electrode stack 420 remain in alignment on alignment fixture 450. Positioning cover 110 over electrode stack 420 includes inserting feedthrough pins 114 such that pin 114A extends through coincident aperture 435A in tabs 432, and pin 114B extends through coincident aperture 445A in tabs 442.

The assembled cover 110 and electrode stack 420 are removed from alignment fixture 450. In addition, the end of feedthrough pin 114A may be welded and/or crimped to electrode stack 420 opposite coincident aperture 435A, and the end of feedthrough pin 114B may be welded and/or crimped to electrode stack 420 opposite coincident aperture 445A.

As shown in FIG. 13C, once electrode stack 420 is secured to cover 110, casement 111 is positioned over electrode stack 420. The interface between cover 110 and casement 111 may then be welded to provide a battery with a substantially sealed enclosure including electrode stack 420. In some examples, the battery may also include a fill port (not shown) and liquid electrolyte may then be added to the battery via the fill port.

Various examples of the invention have been described. These and other examples are within the scope of the following claims.

The invention claimed is:

1. A battery comprising:
 - a battery case forming a substantially sealed enclosure;
 - an electrode stack within the enclosure, the electrode stack including a first set of plate electrodes and a second set of plate electrodes, the plate electrodes in the second set alternating with the plate electrodes in the first set within

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the electrode stack and one or more separators positioned between each pair of adjacent plate electrodes in the first and second set of plate electrodes, wherein the first set of plate electrodes combine with the second set of plate electrodes to form at least one voltaic cell, the first set of plate electrodes forming a cathode of the voltaic cell and the second set of plate electrodes forming an anode of the voltaic cell, wherein the plate electrodes in the first and second sets of plate electrodes each includes a conductive substrate serving as a current collector, and an electrode material disposed over the current collector, wherein the conductive substrate includes a conductive tab that does have the electrode material coating, wherein the electrode stack includes a first set of one or more spacers are positioned between each adjacent tab of the conductive tabs in the first set of plate electrodes, wherein the electrode stack further includes a second set of one or more spacers are positioned between each adjacent tab of the in the first set of plate electrodes; wherein the conductive tabs in the first set of plate electrodes and the first set of spacers are aligned to form a first coincident aperture that extends through the first set of plate electrodes and the first set of spacers, wherein the conductive tabs in the second set of plate electrodes and the second set of spacers are aligned to form a second coincident aperture that extends through the second set of plate electrodes and the second set of spacers, wherein the conductive tabs in the first set of plate electrodes and the first set of spacers are further aligned to form a third coincident aperture that extends through the first set of plate electrodes and the first set of spacers, wherein the conductive tabs in the second set of plate electrodes and the second set of spacers are further aligned to form a fourth coincident aperture that extends through the second set of plate electrodes and the second set of spacers; and a first feedthrough including a first feedthrough pin extending through the battery case and through the first coincident aperture, wherein the first feedthrough pin serves as a positive terminal for the battery; and a second feedthrough including a second feedthrough pin extending through the battery case and through the second coincident aperture, wherein the second feedthrough pin serves as a negative terminal for the battery, wherein the first coincident aperture and the third coincident aperture combine to facilitate alignment of the conductive tabs in the first set of plate electrodes and the spacers in the first set of spacers during assembly of the electrode stack, wherein the second coincident aperture and the fourth coincident aperture combine to facilitate alignment of the conductive tabs in the second set of plate electrodes and the spacers in the second set of spacers during assembly of the electrode stack, wherein the third coincident aperture and the first coincident aperture are orientated differently in the plate electrodes of the first set of plate electrodes than the fourth coincident aperture and the second coincident aperture in the plate electrodes of the second set of plate electrodes to prevent interchanging plate electrodes of the first set of plate electrodes with plate electrodes of the second set of plate electrodes within the electrode stack during assembly of the electrode stack,

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wherein the spacers in the first set of spacers are interchangeable with the spacers in the second set of spacers for assembly of the electrode stack.

2. The battery of claim 1, wherein the conductive tabs in the first set of plate electrodes and the first set of spacers are further aligned to form a fifth coincident aperture that extends through the first set of plate electrodes and the first set of spacers, wherein the conductive tabs in the second set of plate electrodes and the second set of spacers are further aligned to form a sixth coincident aperture that extends through the second set of plate electrodes and the second set of spacers, wherein the third coincident aperture and the fifth coincident aperture combine to facilitate alignment of the conductive tabs in the first set of plate electrodes and the spacers in the first set of spacers during assembly of the electrode stack, and wherein the fourth coincident aperture and the sixth coincident aperture combine to facilitate alignment of the conductive tabs in the second set of plate electrodes and the spacers in the second set of spacers during assembly of the electrode stack.

3. A battery comprising:
 a battery case forming a substantially sealed enclosure;
 an electrode stack within the enclosure, the electrode stack including a first set of plate electrodes and a second set of plate electrodes, the plate electrodes in the second set alternating with the plate electrodes in the first set within the electrode stack,
 wherein the first set of plate electrodes combine with the second set of plate electrodes to form at least one voltaic cell, the first set of plate electrodes forming a cathode of the voltaic cell and the second set of plate electrodes forming an anode of the voltaic cell,
 wherein the plate electrodes in the first and second sets of plate electrodes each includes a conductive substrate serving as a current collector, and an electrode material disposed over the current collector, wherein the conductive substrate includes a conductive tab that does have the electrode material coating,
 wherein the conductive tabs in the first set of plate electrodes are aligned to form a first coincident aperture that extends through the first set of plate electrodes,
 wherein the conductive tabs in the second set of plate electrodes are aligned to form a second coincident aperture that extends through the second set of plate electrodes,
 wherein the conductive tabs in the first set of plate electrodes are further aligned to form a third coincident aperture that extends through the first set of plate electrodes,
 wherein the conductive tabs in the second set of plate electrodes are further aligned to form a fourth coincident aperture that extends through the second set of plate electrodes; and
 a feedthrough including a feedthrough pin extending through the battery case and through the first coincident aperture, wherein the feedthrough pin serves as a positive terminal for the battery; and
 a conductive element extending through the second coincident aperture, wherein the conductive element serves to electrically connect the conductive tabs in the second set of plate electrodes at the negative potential for the battery,
 wherein the first coincident aperture and the third coincident aperture combine to facilitate alignment of the con-

ductive tabs in the first set of plate electrodes during assembly of the electrode stack,
 wherein the second coincident aperture and the fourth coincident aperture combine to facilitate alignment of the conductive tabs in the second set of plate electrodes 5 during assembly of the electrode stack,
 wherein the third coincident aperture and the first coincident aperture are orientated differently in the plate electrodes of the first set of plate electrodes than the fourth coincident aperture and the second coincident aperture 10 in the plate electrodes of the second set of plate electrodes to prevent interchanging plate electrodes of the first set of plate electrodes with plate electrodes of the second set of plate electrodes within the electrode stack during assembly of the electrode stack. 15

4. The battery of claim 3,
 wherein the feedthrough is a first feedthrough, wherein the feedthrough pin is a first feedthrough pin,
 wherein the battery further comprises a second feedthrough that includes the conductive element 20 extending through the battery case, wherein the conductive element is a second feedthrough pin, and
 wherein the second feedthrough pin serves as a negative terminal for the battery.

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